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EFFECT OF AIR FILTER CONDITION ON PETROL VEHICLE FUEL ECONOMY FOR TWO-WHEELER

Anup A. Naukarkar[1], Kiran K. Jadhao[2], Abhijit G. Wadhai[3], Suchit A. Chavan[4]

[1-4]Dept. of Mechanical Engineering, BNCOE, Pusad, Maharashtra, India,
[1]anupnaukarkar97@gmail.com, [2]kkjadhao@gmail.com, [3]abhijitwadhai13@gmail.com,
[4]suchitdeshmukh4@gmail.com

ABSTRACT

The importance of the engine air induction system has recently increased because of governmental engine exhaust particulate and evaporative emission regulations. Air filter provided on the engine intake is subjected to increased levels of abuse due to the diverse driving conditions. An innovative air cleaner design are required to maximize the filtration performance, improve flow management, improve engine durability and extend air cleaner service life. This study addresses the issue of air filter replacement to improve the fuel economy. An automobile manufacturer namely HERO declared air filter replacement for its models ranging from 12,000 km to 15,000 km. According to the same recommendations, periodicity must be reduced by a half, if conditions of use include dusty roads and exploitation of the vehicle in urban conditions. In this study, the different air filter cartridges from two-wheeler of the same model and type were collected. The influence of air filter clogging on performance of vehicle mileage was analyzed. Using an air filter integrity testing device, the maximum permissible pressure drop at different air velocities was determined. The road test on Hero Passion Pro model of 2014 has been performed for vehicle mileage by using the air filter sample. At last data has been collected for various samples at different operating condition and analyzed. Finally, the recommendation for air filter replacement has been carried out in a fuel economy range.

Key words: *Air induction system, engine air filter, Hero Passion Pro model, an air filter integrity testing device, vehicle mileage, etc.*

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1. INTRODUCTION

All internal combustion engines require supply of air. This air must be clean, dry, fresh and cool. Unfiltered air can rapidly wear out an engine. In a short period of time the engine can lose compression and power, start to emit heavy smoke due to the improper supply of an air[1].

Under normal highway conditions, the air consumed by a 16 liter engine contains almost 20 kg of dirt/contaminants per 62,500 miles (100,000 km). There is no room for compromise. The air intake is an open loop system, and the air filter only has one opportunity to filter the contaminant out of the intake air. Air filters are essential for engines and the air that these engines 'breathe' needs to be as clean as possible. Plugged air filters reduce engine performance, create higher fuel consumption, increase exhaust fumes and are harmful to the environment[5].

The tests by major engine manufacturers have shown that as little as two tablespoons of dirt can wear out the engine within very short time. On paved roads, the dust content of the air averages 1 $mg.m^{-3}$, however, on unpaved roads and on construction sites the dust content can be as high as 40 $mg.m^{-3}$. This means that depending on the roads and operating conditions a medium sized engine can draw in up to 50 g of dust over 1000 km, the size of dust particles varies from 0.01 mm till 2 mm. The average efficiency of air filters is 99.8 % for passenger vehicles and 99.95 % for commercial vehicles. Efficiency remains constant throughout the engine speed range. As shown in fig. 1.1, as the air filter builds a dust film, the holes in the media become smaller, and the filter becomes more efficient at trapping dirt. As the filter traps dirt, it is more difficult for the air to pass through the filter, and restriction increases in the air induction system. Air filter restriction usually remains low through most of the filter service life, and then increases rapidly at the end. The value of air filter restriction is the key parameter to be used considering filter replacement[1]. The Comparison between new air filter and clogged filter of Hero Passion Pro bike is shown in fig.1.1.

Fig. 1.1: Comparison between new air filter and clogged filter

A wide variety of filter media can be configured to design engine air cleaners with high performance levels. Typical media used in the engine air filter design are the following:

- Cellulose fiber paper media with phenolic resin binder system;
- Cellulose/synthetic papers blend paper media;
- Synthetic fiber paper media;
- Multi-layered cellulose/synthetic felt media;
- Dual stage filters using reticulated foams or felts as pre-filters[1].

The function and design of intake air filters must address the following:

- Engine durability;
- Filtration;
- Flow management;
- Water/snow ingestion management;
- Pressure or head loss constraints;
- Overall noise, vibration, and temperature standards;
- Competitive pricing requirements;
- Service requirements;
- Packaging;
- Styling/appearance;
- Emissions[2, 8].

Fig. 1.2: Air Filter Samples of Hero Passion Pro

An air filter manufacturer has been suggested that when an air filter becomes dark in a colour as shown in fig. 1.2, air filter should replace at that time. Also, most of automobile manufacturer has been suggested to replace an air filter in a specified kilometer range, as for the most of bike of Hero automobile ranges from 12,000 km to 15,000 km. But, from the colour and the kilometer range of air filter, it cannot be predicted that the filter should replace. It is totally depends on environment conditions under which the vehicle is running and the technical condition of a vehicle.

2. LITERATURE REVIEW

Several researchers were conducted their studies on the Performance of Engine intake air filtration systems. Influence of air filter clogging on engine performance like fuel consumption, emissions, torque, load capacity, etc has been analyzed.

Jaroszczyk, Wake, et. al., (1993)[10], studied that proper filtration systems make engines more fuel efficient; however, they gave no data or reference information to support this claim. The Organization for Economic Co-operation and Development (OECD) claimed [11] in a 1981 report 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. According to 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.

Kevin Norman, et. al., (2009)[2], conducted the study on the effect of intake air filter condition on vehicle fuel economy. It was observed that a reduction in performance and acceleration of the engine under clogging of air filter. Both the studies on diesel and gasoline 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.

Maris Gailis, et. al., (2011)[1], had evaluated current periodicity of engine air filter replacement to determine the influence of this operation on some vehicle performance parameters. Periodicity of motor air filter replacement, declared by the automobile manufacturer Renault ranges from 30,000 km to 1,20,000 km, depending on the model and engine type. According to the same recommendations, periodicity must be reduced by a half, if conditions of use include dusty roads and exploitation of the vehicle in urban conditions. The aim of the research was to evaluate the criteria, according to which actual replacement of motor air filters was performed and to measure the influence of air filters with different levels of use on the engine performance. The influence of air filter clogging on several vehicle

exploitation parameters, such as engine power and fuel consumption was analyzed.

3. AIM AND OBJECTIVES

3.1 Aim of Work

To investigate an influence of Hero Passion Pro air filters clogging on vehicle mileage by using an air filter integrity testing device.

3.2 Objectives of Work

1. To investigate the effects of used air filters on fuel economy and performance of vehicle.
2. To compare the results of pressure drop and fuel consumption testing of an air filter samples and suggest the critical pressure drop limit.
3. To give the recommendation for actual replacement of air filter in a fuel economy range.

4. METHODOLOGY

Following steps have been adopted to investigate an influence of air filter condition on fuel economy:

1. The first stage was to go with an air filter testing on air filter integrity testing device to determine the air flow restriction by using pressure drop method.
2. In the second stage, the fuel consumption test for various air filter samples was conducted on Hero Passion Pro Bike at different vehicle speed range by using average kit.
3. In the last stage, the pressure drop and fuel consumption test results of an air filter samples were analyzed for the actual replacement of an air filter in a fuel economy range.

5. EXPERIMENTAL WORK

5.1 Test Facilities

Pressure drop test was conducted at ICE laboratory of Mechanical Engineering Department at Babasaheb Naik College of Engineering, Pusad, Dist. Yavatmal, Maharashtra, India. The air filter testing device was connected on universal air compressor of 7.5 Hp as shown in fig. 5.1. The fuel consumption and vehicle performance test was performed on a Hero Passion Pro bike as shown in fig. 5.2, which was available from Sony Automobile Hero Showroom, Pusad, Dist. Yavatmal, Maharashtra, India.

Fig. 5.1: Universal Air Compressor of 7.5 Hp

Fig. 5.2: Hero Passion Pro

5.2 Pressure Drop Test Setup

The air filter integrity testing device is used to test the cylindrical pleated paper media air filter of most of the Hero bikes. In this test setup, cylindrical casing is used to fix an air filter, whose inlet pipe is tangential to the casing and connected to the universal air compressor of 7.5 Hp. The outlet pipe is axially connected to the cover plate and opened to the atmosphere, where it is connected to anemometer to measure the outlet velocity of air. The schematic diagram of air filter testing setup for air velocity measurement by using anemometer is shown in fig. 5.3.

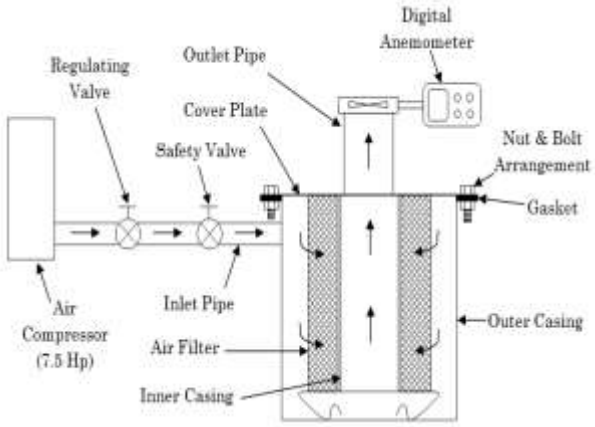

Fig. 5.3: The schematic diagram of air filter testing setup

5.3 Pressure Drop Test

Fig. 5.4: Air Filter Integrity Testing Device

The pressure drop test was conducted on air filter integrity testing device as shown in fig. 5.4. Firstly, the velocity of air is measured for empty casing with addition of various losses of a casing. After that, new filter is tested. Simultaneously, the used air filters of same model are tested for the value of velocity of air.

By using the values of velocity of air, the dynamic pressure for corresponding filters are calculated by using a relation, which is derived from the Bernoulli's equation. The relation of dynamic pressure is as given below,

$$q = \frac{1}{2} \times \rho \times v^2$$

Where,

q = Dynamic Pressure (Pa)

ρ = Density of air (kg/m^3)

v = velocity of air (m/s)

Then, the pressure drop of used air filters are calculating by taking the difference of dynamic pressure of new air filter and corresponding used air filters as mentioned in table 5.1.

Table 5.1: Different kilometer range air filter samples of Hero Passion Pro Bike used for testing purpose

Sr. No.	Air Filter Range (km)	Actual Reading (km)	Hero Passion Pro Air Filter
1	0	0	
2	0-3000	1600	
3	3000-6000	4500	
4	6000-9000	8000	
5	9000-12000	11000	
6	12000-16000	15000	
7	16000-20000	20000	

5.4 Fuel Consumption Test

The fuel consumption 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 2014 model HERO PASSION PRO (BS-III).

The fuel consumption tests were conducted on a nearly 10 km range of road having coefficient of friction of about 0.7 for dry road. An average kit is used for testing purpose by filling it up to 100 ml mark as shown in fig. 5.5. During the test runs vehicle weight and speed was kept constant, no brake applied, the headlight turned on to low beam and the tyre pressure was also monitored. During each run the odometer reading and time required to complete each run was noted as shown in fig. 5.7. Also, the wind resistance is measured by using anemometer. The readings were measured at different vehicle speeds i.e. between economy (40-45 km/hr), average economy (55- 60 km/hr) and above economy (75-80 km/hr) for the same air filter samples as mentioned in table 5.1.

Fig. 5.5 : Average Kit with 100ml petrol

Fig. 5.6 : Air Filter Fitting in vehicle

Fig. 5.7 : Some Odometer Readings of Bike

6. RESULTS AND DISCUSSION

6.1 Result of Intake Air Parameters in Actual Condition of Motorcycle

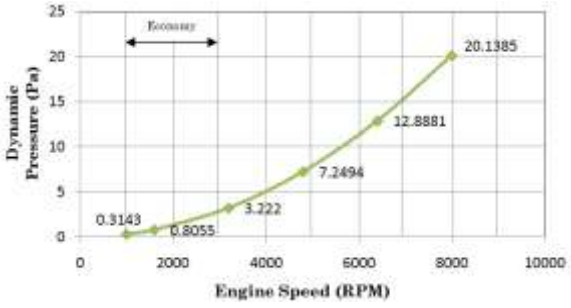

Fig. 6.1: Intake air parameter in Actual Condition of Motorcycle at Various

The theoretical values of maximum permissible dynamic pressure of an air induction system has been showed that as the speed of an engine is increased, the air requirement of an engine is more. Therefore, the value of air pressure is also increased as shown in fig. 6.1. The maximum air pressure required for Hero Passion Pro bike is 20.1385 Pa at a maximum speed of 8000 RPM. An economical speed range of bike is also mentioned.

6.2 Results of Pressure Drop at Economical Speed Range for Air Filter Samples

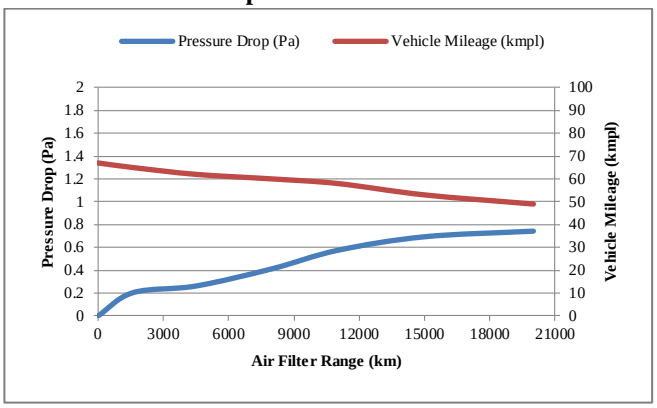

Fig. 6.2: Pressure Drop at Inlet Velocity of 2.5 m/s for Economical Speed Range

In the pressure drop and fuel consumption test, it has been observed that due to increase in air flow restriction of air filter, the pressure drop after the air filter is increased. Therefore, the air-fuel ratio of an engine is decreased and there is a reduction in a vehicle mileage of a bike. From the fig. 6.2, it is concluded that if the bike is continuously running in an economical speed range (of 40-45 km/hr), the air filter can be used above a range which is recommended by an air filter manufacturer. Also, it does not show significant impact on mileage of bike by air flow restriction within this economical speed range.

6.3 Results of Pressure Drop at Average Economical Speed Range for Air Filter Samples

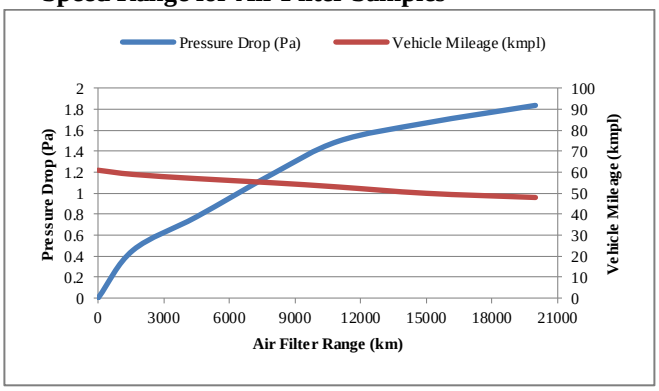

Fig. 6.3: Pressure Drop at 5 m/s of Inlet Velocity for Average Economical Speed Range

From the fig. 6.3, it has been observed that due to the increase in pressure drop after the air filter, there is certain reduction in values of vehicle mileage. As a bike is running at moderate speed range (of 55-60 km/hr), initially the pressure drop is increased rapidly. Due to requirement of air is more as compared to previous condition. Therefore, the used air filter cannot fulfil the requirement of an engine at moderate speed and the air-fuel ratio of an engine is decreased. So, the air filter should replace as far as possible. The critical pressure drop limit at moderate engine speed is 1.12 Pa for a vehicle mileage of 56 kmpl. At which, the actual replacement an air filter should take placed.

6.4 Results of Pressure Drop at Above Economical Speed Range for Air Filter Samples

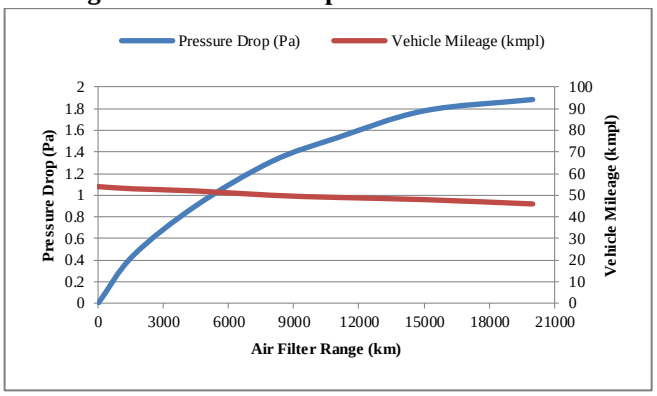

Fig. 6.4: Pressure Drop at Inlet Velocity of 7.5 m/s for Above Economical Speed Range

The fig. 6.4 shows that, due to the increase in pressure drop across the air filter, there is certain reduction in values of vehicle mileage. As a bike is running at high speed range (of 75-80 km/hr), the pressure drop is increased rapidly. As the requirement of air is more as compared to previous two conditions. Therefore, the used air filter cannot fulfil the requirement at high engine speed. It has possibility that air filter may damaged sometimes at this speed and dust particles may passed through the paper media. The critical pressure drop limit at high engine speed is 1.02 Pa for a vehicle mileage of 51 kmpl. At which, the actual replacement of air filters should take place.

However at normal driving condition, the critical pressure drop limit is an average of both average economical and above economical speed range of 1.07 Pa for vehicle mileage of 53.5 kmpl.

7. CONCLUSION

An air filter integrity testing device should use to test the used air filter for its air flow restriction value. If the air filter readings goes across the specified value of pressure drop of 1.07 Pa, replaced it. As the air filter is not replaced in specified limit, the vehicle mileage is reduced and this will increase the fuel cost.

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