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Experimental Investigation of Pressure Drop Testing For Two-Wheeler Air Filter

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ABSTRACT

The role of engine air induction system increased because of evaporative emission regulations. The experiences of usage, technical condition of vehicle are linked with best system of technical servicing. According to automobile manufacturer Hero recommendations for air filter replacement ranging from 12,000 km to 15,000 km. The aim of this work is to study different air filter performance for two wheelers. In this air filter integrity testing device is developed. Initially, various air filter of Hero passion Pro model has collected and tested and then effect of air filter clogging on performance of two-wheeler is analyzed. Finally, maximum pressure drop at different air velocities are determined and performance of both air filter type in clogged and new condition in terms of pressure drop is also studied.

Key words : *Air induction system, air filter, technical servicing of vehicles, Hero Passion Pro model, An air filter integrity testing device, velocity of air, pressure drop, etc.*

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;

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- 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.

1. 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.

Introducing more air into the air fuel mixture can improve combustion efficiency to enhance engine performance (Kamil, Rahman, & Bakar, 2011[9]; Sundar Raj & Sendilvelan, 2010[11]). The simplest way to increase the air flow rate is to reduce the air flow restriction through the air filter element. Modern internal combustion (IC) engines use an air intake system for filtering the atmospheric air into clean air and routing the clean air into the combustion chambers (Abdullah et al., 2009[7]; Bhaskar, Nagarajan, & Sampath, 2010[8]; Mohanamurugan & Sendilvelan, 2011[10]; Van Basshuysen & Schäfer, 2004[12]; Yusaf, Baker, Hamawand, & Noor, 2013[13]).

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.

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.

Mathews V. John, et. al., (2015)[4], had conducted study on the effect of OEM style and aftermarket performance air filters on vehicle parameters. 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.

2. AIM AND OBJECTIVES

3.1 Aim of Work

To develop an air filter integrity testing device for automobile, this can evaluate the current periodicity of engine clogged air filter replacement.

3.2 Objectives of Work

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1. To investigate the effects of used air filters on the performance of the vehicle.
2. To decide the critical pressure drop limit.
3. To give the recommendation for actual replacement of air filter.

3. METHODOLOGY

Following steps have been adopted to develop an air filter integrity testing device for automobile:

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. By comparing the dynamic pressure value for new air filter with the values of used air filters, the pressure drop was calculated for respective air filter samples.
3. In the last stage, the pressure drop results of an air filter samples were analyzed for the actual replacement of an air filter.

4. DESIGN & FABRICATION

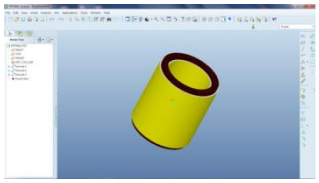

Fig. 5.1: Engine Air Filter

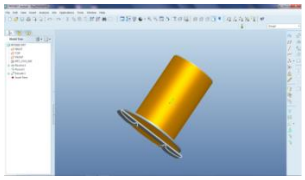

Fig. 5.2: Inner Casing

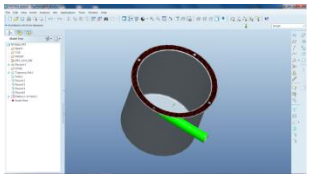

Fig. 5.3: Outer Casing

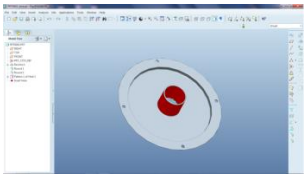

Fig. 5.4: Cover plate

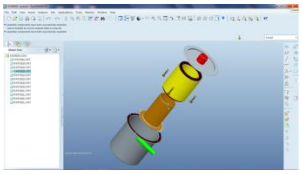

Fig. 5.5 (a): Exploded View

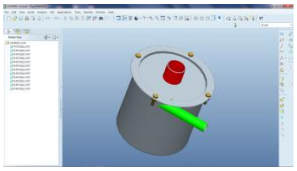

Fig. 5.5 (b): Unexploded View

These all the parts of an air filter integrity testing device as shown in above figures were designed on Pro/Engineer CAD software. The device is specifically designed for Hero Passion Pro air filter. Its shape and size is based on the design of air filter.

5. EXPERIMENTAL SETUP

6.1 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. 6.1.

Fig. 6.1 : Universal Air Compressor of 7.5 Hp

6.2 Test Setup

This 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. 6.2.

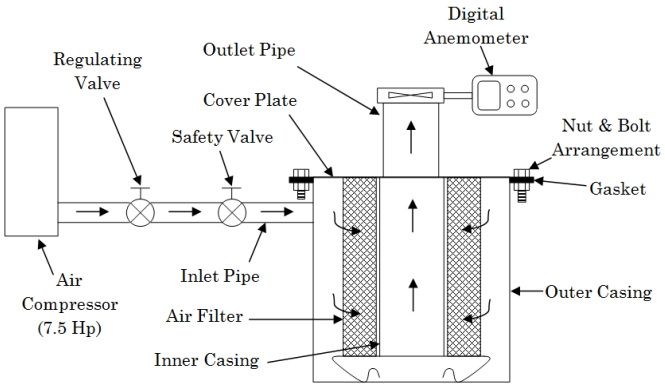

Fig. 6.2: The schematic diagram of air filter testing setup

All the parts which are used to complete this test setup are specifically designed for an air filter of Hero bikes. According to the standard design of an air filter used on test bench, a design of the device will be changed.

7. EXPERMENTAL STUDY

7.1 Pressure Drop Test

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Fig. 7.1: Air Filter Integrity Testing Device

The pressure drop test was conducted on air filter integrity testing device as shown in fig. 7.1. 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 7.1.

Table 7.1 : 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	

8. RESULTS AND DISCUSSION

8.1 Result of Intake Air Parameters in Actual Condition of Motorcycle

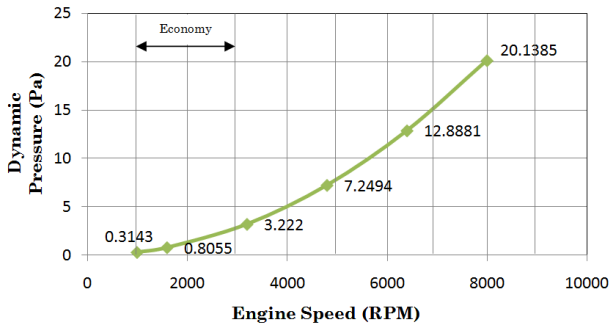

Fig. 8.1: Intake air parameter in Actual Condition of Motorcycle at Various

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. 8.1. The maximum air pressure required for Hero Passion Pro model is 20.1385 Pa at a maximum speed of 8000 RPM. An economical speed range of bike is also mentioned.

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

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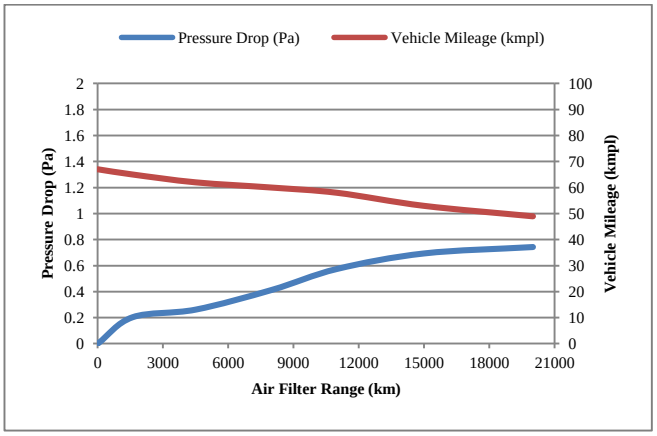

Fig. 8.2: Pressure Drop at Inlet Velocity of 2.5 m/s for Economical Speed Range

The measurement of the pressure drop test showed 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. 8.2, 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.

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

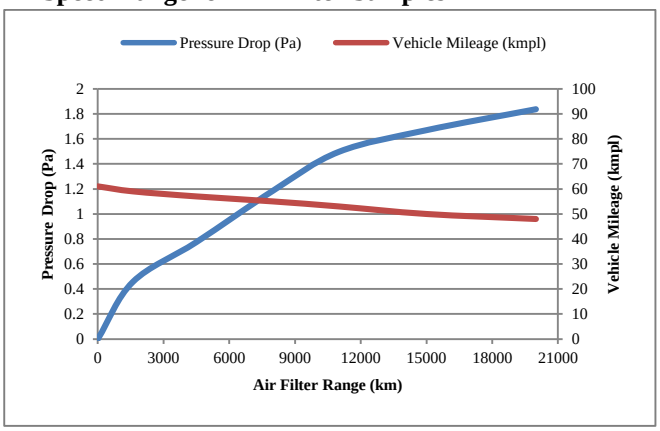

Fig. 8.3: Pressure Drop at 5 m/s of Inlet Velocity for Average Economical Speed Range

From the fig. 8.3, 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. 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.

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

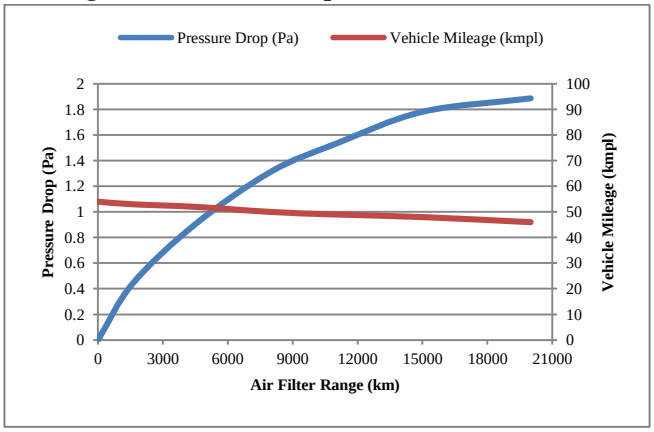

Fig. 8.4: Pressure Drop at Inlet Velocity of 7.5 m/s for Above Economical Speed Range

The fig. 8.4 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 air filters should be replaced.

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.

9. CONCLUSION

In this different air filter at various driving condition is evaluated and conclusion is drawn. The pressure drop test conducted shows that, critical pressure drop limit at different driving condition such as high speed 1.02 Pa at vehicle mileage of 51 kmpl. Similarly, under normal driving condition is 1.07 Pa at 53.5 kmpl. It has been suggested that air filter reading of pressure drop goes beyond a specified limit of 1.07 Pa, air filter should be replaced.

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