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AIR FILTER CLOGGING EFFECTS ON THE MANIFOLD INTAKE PRESSURE AND TEMPERATURE OF FOUR STROKE SPARK IGNITION GASOLINE ENGINE

A. B. Hassan *[1], A. Bitrus [2] and I. Yahuza[3]
*[1] Department of Mechanical Engineering, Federal University of Technology, P.M.B. 65, Minna, Niger State - Nigeria., *abhassan@futminna.edu.ng*
[2]Department of Mechanical Engineering, Niger State Polytechnic, Zungeru, Niger State - Nigeria, *rockricg4u@yahoo.com*
[3]Department of Automotive Engineering, Abubakar Tafawa Balewa University, Bauchi, Bauchi State - Nigeria, *iyahuza@atbu.edu.ng*
Corresponding Author Contact: +2348034529014.

ABSTRACT

The negative effects of dusty Nigerian roads irrespective of season on engineering devices and systems can not be overemphasized. This non-seasonal phenomenon and its implications on engineering devices and system need to be studied in order to understand the extent of the negative implications. The effects of distance coverage on manifold intake pressure and temperature of four stroke spark ignition gasoline engine has been studied extensively. The study was carried out using Minna - Suleja road in Niger State, Nigeria as case study and 2008 model Peugeot 406 as a test vehicle. Distances of 50 km, 150 km and 200 km were covered with three air filters and different studies were carried out which include literatures review, On-Board Diagnostic (OBD) and effects of filters blockage by dust in relation to engine performance. The results of the investigation estimated that an air filter clogging increases with distance plies on dusty tarred road. This increased clogging of air filters with distance cause significant decrease in manifold intake pressure and temperature while on the other hand; it causes more formations of Hydrocarbons (HC), Carbon monoxide (CO), and reduces the formations of Carbon dioxide (CO_2) and Nitric oxide (NO) into the atmosphere. The study therefore recommends that air intake pipes should be incorporated with dust repel materials; filters should be cleaned or changed based on manifold intake pressure and temperature data and not by distance covered by vehicles.

Key Words: *Air Filter System, Manifold Intake Pressure and Temperature, and Four Stroke Spark Ignition Gasoline Engine.*

1.0 INTRODUCTION

Air is not only critical for any life but also vital for the operation of any Internal Combustion (IC) engine. These IC engines utilize heat from the combustion of air and fuel mixture to create to and fro motion of pistons under high pressure that then turns the crankshaft. The power generated cause movement of crankshaft which turns the wheels through a chain or a drive shaft. The generated power can also be used to power other applications such as air conditional system, refrigerator, and alternator through pulleys and belts [1]. The commonly used fuels for IC engines are gasoline (or petrol), diesel, and kerosene; however these fuels release substantial amount of pollutants into the atmosphere and create environmental related problems [1], [2].

IC engine could be four or two stroke type. The four stroke gasoline engine or Spark Ignition (SI) engine takes or sucks in a flammable charge (air and gasoline mixture) in the first stroke, known as suction stroke. The charge is then compressed in a second stroke known as compression stroke and ignited by a timed spark in the third stroke (called expansion on power stroke). After the third stoke is completed, the burned gases are removed from the cylinder during the fourth stroke called the exhaust stroke. A four stroke SI engine operate on Otto Cycle. The four strokes are completed through 720 degree of crankshaft rotation i.e. each stroke consists of 180 degree rotation of crankshaft [3], [4].

The positive impact of IC engine is great. This concept of IC engine has greatly transformed the transportation industries through constant innovations of automobiles, trains, airplanes and trucks. However the atmospheric air used by IC engines contains contaminants such as dust, smog, fumes and other particles. These suspended particles in the inflow air as it is drawn from the atmosphere into the engine are removed by a device called air filter or cleaner. It is a vital component of the four stroke SI gasoline engine. The air filter system has an intake and exit pipes where the required air for engine operation is pass-through and retained within engine cylinder. The air filters lower the intake of contaminants to design specification [5]. However, the concentration of contaminants varies depending on the operating condition; for instance, dust concentration is around 0.1 milligrams per cubic meter in a typical operating condition while off-road condition is around 100 milligrams per cubic meter [6]. The air filter system of 2008 Model Peugeot 406 used in this project as test vehicle is design to prevent debris or macro particles from entering into the engine thereby preventing engine damage. Filter media is made from cellulose and blends of fibers using resin as binder [6].

The state or nature of air intake pipe affects the inflow of air into the engine. For instance, if air is allowed to flow through a twisted pipe and is then compared to an intake pipe that is not twisted; it will be observed that the greater the twist, the harder the resistance to the inflow of air to the air filter system. Similarly blocked air filter media pores would prevent air inflow into the engine. The air filter system are design to allow as much as possible air inflow into the engine, thereby enhancing better combustion of charge to enhance engine performance [5], [7]. Therefore, the rate of air inflow into the engine cylinder and good operating condition at a given speed is directly proportional to power output of any IC engine [4]. The four strokes SI gasoline 2008 model Peugeot 406 used in this project as test vehicle is expected to produce results demonstrating the effect of distance plies on dusty tarred road (Minna-Suleja road in Niger State, Nigeria as a case study) on manifold intake pressure and temperature.

1.2 Statement of Problem

The smooth flow of air through the air filter media enhances engine's efficiency and performance. It ensures right quality and quantity of air by design requirement that passes through the air filter get into the combustion chamber with minimum restriction. The dusty nature of some Nigeria roads could become a threat to the quality and quantity of air (due to filter pore blockage by dust) available for combustion in the vehicles that plies these roads. The smooth flow of air through the filter media is very important as lack of it could decrease engine performance and increase emission due to insufficient air supply for proper combustion [8]. This non-seasonal dusty nature of Nigeria tarred roads and its negative implications on engineering devices and systems need to be studied in order to understand the extent of the negative implications.

1.3 Significant of Study

Smooth flow of air through the air filter system and good operating condition at a given speed ensure good engine performance and better charge combustion in the cylinder. Lack of adequate air intake could cause decrease in manifold intake and temperature thereby affecting engine's performance, and emission negatively [1], [4] and [8]. Hence, this study to investigate the extent of air filter clogging effects on manifold intake pressure and temperature of four stroke SI gasoline engine using Minna –Suleja road as a case study and 2008 Model Peugeot 406 as test vehicle.

1.4 Aim and Objectives

This project investigates into the distance effects on manifold intake pressure and temperature of four stroke SI gasoline engine. The objectives of the study include:

i. To determine air filter clogging with respect to distance plies on tarred dusty road and its effect on manifold intake pressure and temperature of four stroke SI gasoline engine.
ii. To determine other impacts of clogged air filter media with respect to distance plies on dusty tarred road

2.0 RESEARCH METHODOLOGY

2.1 Methodology Applied

This research was conducted to ascertain the effect of distance on manifold intake pressure and temperature of four stroke SI gasoline engine using the research approach shown in figure 2.1 below.

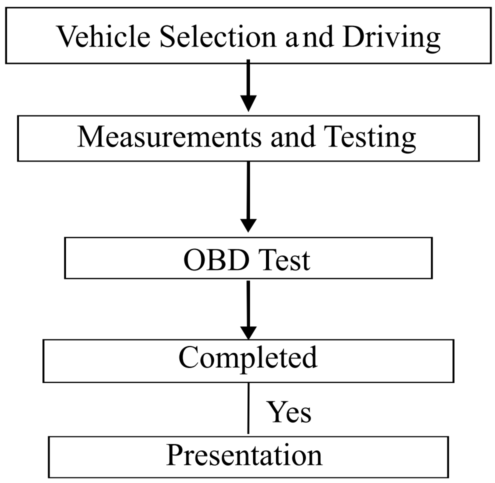

Figure 2.1: Flow Chart of Methodology Applied

2.2 Vehicle Selection

The vehicle selected for testing was based on accessibility, On-Board diagnostics ability and cost. The 2008 Model Peugeot 406 vehicle was selected and sourced from dealers. It was taken and driven for 50 km, 150 km and 200 km on Minna – Suleja road before experimental OBD testing was later carried out.

2.3 Vehicle Driving

The vehicle as selected above was taken for driving. Initially the vehicle was subjected to minimum check list like air filter system leaks. The plugs and battery were also checked to ensure they are in good condition. A weak plug will cause an ignition challenge while weak voltage battery (of less than 12.4 volts and charging voltage of less than 13.5 to 15.0 volts) could affect engine starting ability and fuel economy negatively. The new filters of the test vehicle were purchased and their weights were measured to be 177 grams each.

2.4 On-Board Diagnostic (OBD) Test

The test vehicle was driven to Peugeot Automobile Company, Minna branch, Niger State, Nigeria. The manifold intake pressure and temperature under idle and high speed conditions were determined using the schematic diagram shown in figure 2.2.

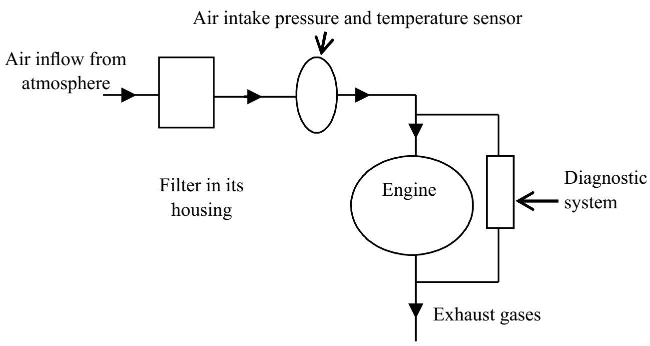

Figure 2.2: Schematic Diagram of OBD Test

The first step of the experimental research was the purchase of fitters from Peugeot spare part dealer in Minna, Niger State, Nigeria. The filters weights were determined and recorded before and after the vehicle driving. Four filters were involved in the investigation and the filters were labeled as 0 km, 50 km, 150 km and 200 km respectively. The vehicle was driven to Peugeot Automobile Company, Minna, Niger State. Each of filters was inserted into air filter housing with the aid of screw driver and tested. The new (0 km) and no filter condition were also tested for comparison purpose.

The OBD system was connect to the vehicle OBD connection port in order to investigate the effect manifold intake pressure under each filter within specified engine speed range. The manifold intake pressure was continuously monitored for the duration of five minute after commencement of each filter and no filter testing process. The test was formed under an idle and high engine speed conditions. The range considered for idle and high speed was 704 to 2400 revolutions per minute (rpm) and 2500 to 4500 rpm. The manifold intake temperature for each filter and no filter condition was also monitored and recorded at the same idle and high speed. The results of value obtained from the experiments are presented in tables and their respective corresponding graphs in the next section.

3.0 RESULTS AND DISCUSSIONS

3.1 Results

OBD Test Results

Five filter set ups: a new filter; 50 km, 150 km and 200 km filters; and no filter conditions were tested using 2008 Model Peugeot 406 as the test vehicle. The respective stable values of manifold intake pressure and temperature under an idle and high speed of 750 ± 50 rpm and 3000 ± 500 rpm for the new, used and no filter condition tests carried out on the OBD system are presented in Table 3.1(a) and 3.1(b) respectively.Manifold Intake Pressure (mb)

Table 3.1(a): The Idle Speed Results of OBD Test for New, Used and No Filter Condition

S/N	Filter State	Distance Covered (km)	Manifold Intake Pressure (mb)	Manifold Intake Temperature (^{O}C)
1.	New	0	390	49
2.	Used	50	390	49
3.	Used	150	362	48
4.	Used	200	355	47
5.	No filter	-	437	50

Manifold Intake Pressure (mb)

Table 3.1(b): The High Speed Results of OBD Test for New, Used and No Filter Condition

S/N	Filter State	Distance Covered (km)	Manifold Intake Pressure (mb)	Manifold Intake Temperature (^{O}C)
1.	New	0	234	48
2.	Used	50	234	45
3.	Used	150	230	43
4.	Used	200	218	43
5.	No filter	-	250	51

The corresponding graphs showing the results of monitoring of manifold intake pressure for new, used and no filter condition at an idle condition are shown below in figure 3.1(a) and 3.1(b

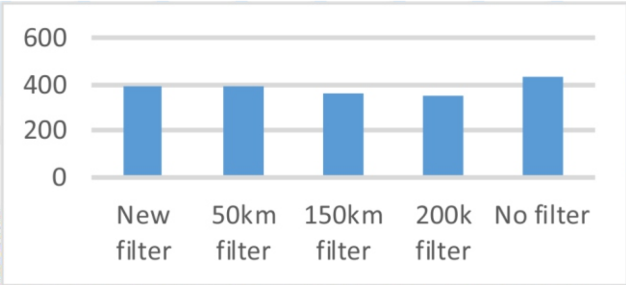

Figure 3.1(a): The Manifold Intake Pressure for New, Used and No filter OBD Test at an Idle Speed

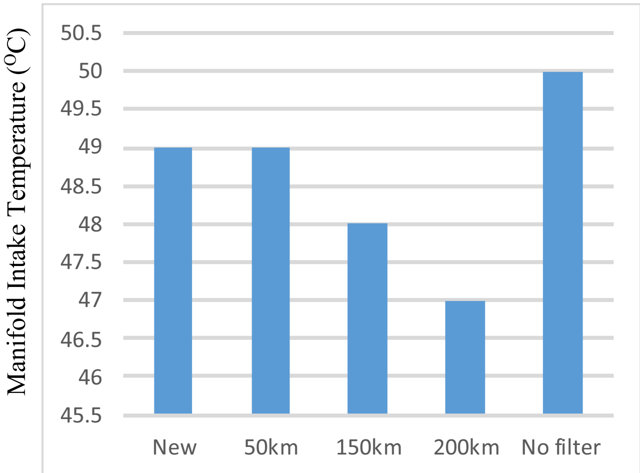

Figure 3.1(b): The Manifold Intake Temperature for New, Used and No Filter OBD Test at an Idle Speed

The idle speed results of the OBD test shows clearly that the manifold intake pressure of the new and 50 km filters are of the same value (390 mb). Also their air intake temperatures were of equal value (49^{0}C). The result also indicates that the air intake pressure of the 150 km filter was 28 mb less when compared to the air intake pressure of the new filter; while the new filter has the highest manifold intake pressure value which is 47 mb greater than compared to the new filter manifold intake pressure.

The above results also indicate similar pattern for the manifold intake temperature where the value of the 150 km and 200 km filters were 1^{0}C and 2^{0}C less when compared to the intake temperature value of the new filter. However, the new filter has the highest value of manifold intake temperature. Similar graphs for the new, used and no filter OBD test showing the manifold intake pressure and temperature at high speed are shown in figure 3.1(c) and 3.1(d) below.

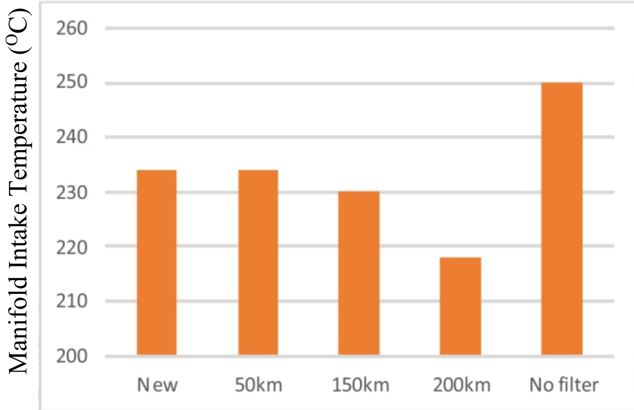

Figure 3.1(c): The Manifold Intake Pressure for New, Used and No Filter OBD Test at High Speed

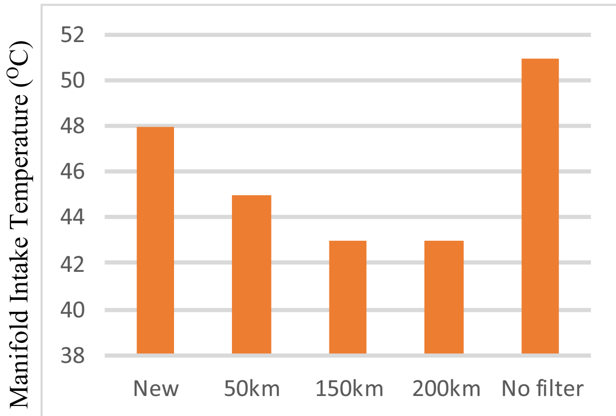

Figure 3.1(d): The Manifold Intake Temperature for New, Used and No Filter OBD Test at High Speed

The high speed results [Figure 3.1(c)] of the new and 50km filter show that the manifold intake pressure were of the same value (234 mb) while the intake temperature of the 50 km filter (51^{0}C) was 3^{0}C less than that of the new filter (48^{0}C). Also the results show that the manifold intake pressure of 150 km and 200 km filters were 4 mb and 16 mb less when compared to the air intake pressure of the new filter. While the new filter has the highest value of intake pressure which is 16 mb greater when compared to the new filter manifold intake pressure. The manifold intake temperature of 150 km and 200 km filters were of the same value (43^{0}C) and the new filter has the highest value of the air intake temperature (51^{0}C). The above results also show that as distance increases, the air passage reduces (due to filter pores blockage by dust) thereby causing the reduction in manifold intake pressure and temperature.

3.2 Discussions

The experimental results in figure 3.1(a) and 3.1(b) indicate that the resistance to air flow through the used filters increases steadily with more distance coverage on the road. This resistance is caused by the filter fiber pores blockage by dust. This blockage is expected to increase with distance coverage. The new and 50 km filters equal value for intake pressure and temperature show that the filters fiber pores blockage was not significant enough to cause variation in air passage through the filters at an idle and high speed [11].

The results also show decrease in air intake pressure [figure 3.1(a) and 3.1(c)] and temperature [figure 3.1(b) and 3.1(d)] of the 150 km and 200 km filters when compared to the 50 km filter. This indicate that the pores of the filters were getting blocked which caused increased resistance to air flow through the air passages [9], [10]. The slight decrease in the intake pressure and temperature of the 150 km filter shows that more air passages of the filter got blocked. This values further decrease slightly as the distance coverage was increased to 200 km. thus, with more distance coverage the resistance to air flow through the filter pores is expected to increase as more pores got blocked. The result obtained shows that manifold intake pressure and temperature would continuously decrease as clogging of the filter increased with distance. This rate of clogging is expected to be at peak during the Harmattan Season.

4.0 CONCLUSION AND RECOMMENDATIONS

This section presents the concluding remarks and recommendations for further work.

4.1 Conclusion

The main aim of this research is to investigate the effect of air filter clogging on manifold intake pressure and temperature of four stroke SI gasoline engine using 2008 model Peugeot 406 as a test vehicle. It was estimated that vehicle that plies Minna-Suleja road during non-Harmattan and non-rainy season for 50 km, 150 km and 200 km, its filter would get clogged by 23, 38 and 48 grams of dust [12].

It was found from the new and no filter test carried out, manifold intake pressure, and temperature were affected. The results of the new and no filter tests show that the manifold intake pressure and temperature were high since the restriction to air passage were minimum. However, the manifold intake pressure was highest in the no filter condition at both idle and high speed and less emission was released into the atmosphere.

Similar trends in the manifold intake pressure and temperature were also obtained for the 50 km, 150 km and 200 km used filters tests at an idle and high speed. The results show that air inflow into the engine reduces (due to blockage by dust) with increase in distance plies on dusty tarred road. This indicated that the manifold intake pressure and temperature values would reduce with increase in clogging of the filters while the emission gases would be expected to slightly increase with distance. Thus the air flow through the used filters into the engine was less when compared to the new and no filter conditions. This reduction in air volume causes reduction in quantity of air (as well manifold intake pressure and temperature) available for combustion thereby affecting engine performance and emission negatively. The effectiveness of air filters in relation to intake pressure, temperature and emissions is expected to get negatively affected on dusty tarred road as distance plies increases especially during the Harmattan Season.

4.2 Recommendations

i. The cleaner the air that goes into the filter the better the effectiveness of such filter and engine performance. Thus the air intake pipes from the atmosphere should be incorporated with dust repelled materials (further research needed in this regards) to minimize dust intake especially in developing countries were good roads are still challenge.

ii. Air filters should be cleaned or changed based on manifold intake pressure and temperature measurements but not by distance covered by a vehicle. If filters are replaced based on covered distance, engine performance and emission could be negatively affected in the case when the filter gets clogged before reaching the manufacturer's recommended distance. Also if the vehicle is used more often on less dusty road, there is a low possibility of the filter getting clogged earlier than the required distance for replacing it. Thus, the use of intake pressure and temperature would give precise information about when to clean or change the filter.

iii. Vehicle should be incorporated with a means of indicating when it is appropriate to clean its filter from intake pressure and temperature reading. This would provide information on effectiveness of filter with respect to dust blockage.

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