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Distance Effects on the Emission of Four Strokes Spark Ignition Gasoline Engine

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Abstract

The dusty nature of most Nigerian roads irrespective of season has different negative effects on engineering devices and systems. 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 effect of distance coverage on emission of four stroke spark ignition gasoline engine has been studied extensively. The study was carried out using Minna - Suleja road as case study and 2008 model Peugeot 406 as a test vehicle. Distance of 50 km, 150 km and 200 km were covered with three air filters. The results of the investigation estimated that an air filter get clogged by 23, 38, and 48 grams for 50 km, 150 km and 200 km plies on dusty tarred road. This increased clogging of air filters with distance causes more emissions of hydrocarbons (HC), and carbon monoxide (CO), while on the other hand reduce the formation of carbon dioxide (CO_2) and nitric oxide (NO) into the atmosphere. The study therefore recommends that, the inlet of air intake pipes should be incorporated with foam-like dust repel materials. Also, emission directives should be in place after further research using different vehicles categories and fuels.

1. Introduction

The quantity and quality of air is very critical for improving the internal combustion engine (ICE) efficiency, hence, the cleaner the air that goes into the filter the better the effectiveness of such filter, engine performance and emission. A lot of research such as supercharging and turbo charging has been done in order to improve ICE efficiency. ICE are engines in which the combustion occurs within the engine. It utilizes the atmospheric air for fuel atomization and in the combustion of charge to create to and fro motion of pistons (in two or four strokes) under high pressure that then turns the crankshaft [1]. The atmospheric air used by IC engines contains contaminants such as dust, smog, fumes and other particles, whose concentration depends on vehicle operating condition. These suspended particles in the inflow air as it is drawn from the atmosphere into the engine are removed by a vital component called air filter or cleaner. The air filter system has an intake and exit pipes where the required air for engine operation is passed-through and retained within engine cylinder. The air filters lower the intake of contaminants to design specification [2, 3].
The four-stroke gasoline engine or Spark Ignition (SI) engine takes in a flammable charge in the suction stroke (known as first stroke). The charge is then compressed in a second stroke known as compression stroke and ignited by a timed spark in the expansion on power stroke (called third stroke). After the third stoke is completed, the burned gases are removed from the cylinder during

the exhaust stroke. A four stroke SI engine operate on Otto Cycle [4]. The commonly used fuel by ICE is gasoline, diesel or kerosene. However, this fuel combustion could release substantial amount of emission constituents in the form of sulfur oxides, (if the fuel contains sulfur); carbon dioxide, CO_2 (which is the reaction of oxygen with carbon content of the fuel); Nitric oxide, NO (reaction of nitrogen with fuel); Carbon Monoxide, CO (due to incomplete fuel combustion in the cylinder), and unburned hydrocarbons HC, [5].
Studies have shown that the rate of air inflow into the engine cylinder and good operating condition at a given speed is directly proportional to engine performance and emission of any IC engine [6, 7, 8, 9]. This could mean that air filter clogging may negatively affect the emissions of four strokes SI gasoline engine due to blocked air filter media pores that would prevent air inflow into the engine, thereby causing incomplete charge combustion. Therefore, this research is expected to demonstrate the distance effects on the emission of four stroke spark ignition gasoline engine using 2008 model Peugeot 406 as a test vehicle and Minna-Suleja road as a case study.

2. Methodology

This research was conducted to ascertain the effect of distance on air intake pressure, temperature and emission of four stroke SI gasoline engine using the research approach shown in Figure 1.

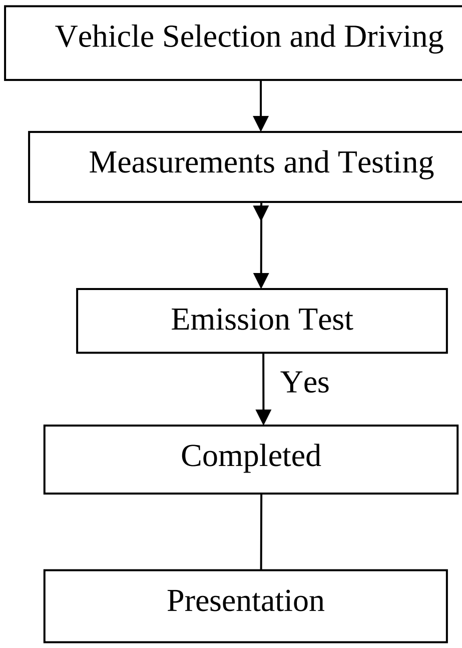

Figure 1: Flow Chart of Methodology Applied

2.1 Vehicle Selection and Condition

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 testing was later carried out. The vehicle as selected was taken for driving. It was a fairly new vehicle with unrolled back digital odometer read 272, 009 mph/kmh and newly serviced. Initially, the vehicle was subjected to minimum check list like air filter system, catalytic converter and exhaust leaks, in order to ensure they are in good condition. 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 engine lubricant and oil filter were also changed to avoid increase in exhaust emissions. The new filters of the test vehicle were purchased and their weights were measured to be 177 grams each.

3. Emission Test and Results

3.1 Emission Test

The test was conducted at Niger state Computerize Inspection Center, Minna, Nigeria using the schematic diagram shown in Figure 2.

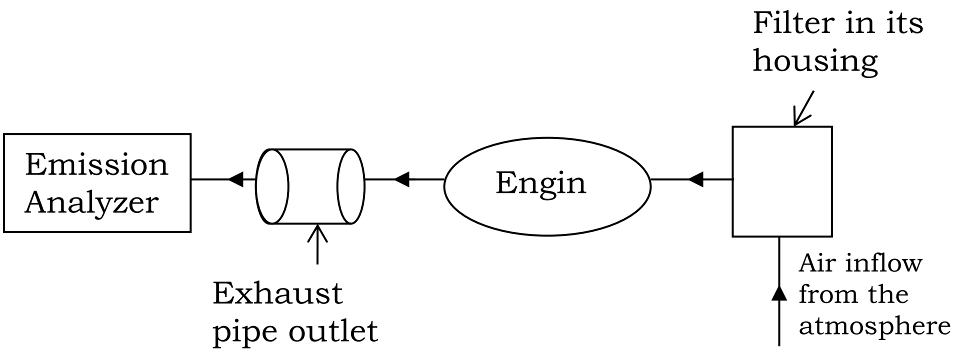

Figure 2: Schematic Diagram of Emission Test

The center provides total vehicle inspection services which include brake, head lamp and emission test. The digital emission tester consists of a monitor for results display; exhaust gases monitoring unit, for signal information processing and transmission of flue gas constitutes. It also, has a power unit, for voltage; current and frequency regulator; and exhaust probe, for sensing exhaust gases and transmitting such gases, to the emission monitoring unit. The gas analyzer required well trained operators to drive the vehicle while the Hydrocarbons (HC), Carbon Monoxide (CO), Carbon dioxide (CO_2), Oxygen (O_2) and Nitric oxide (NO) are measured. The 5-way emission analyzer was used to test the emission of the vehicle for a duration of about two minutes, then calculates the average exhaust gases emission and display the results of HC and NO in constitutes were investigated for new, 50 km, 150 km, 200 km, and no filter, conditions.

The test vehicle was checked for fuel and exhaust leaks. After the minimum check with vehicle engine at OFF Condition before the commencement of the test, the 5-way emission analyzer was warm up for 15 minutes. The analyzer has prescribed factory settings which include acceleration and deceleration for specified seconds for its operators to follow in order to obtain desired results. While waiting for the analyzer to warm up; the air filter in the test vehicle was removed with the aid of a screw driver and replaced with 0 km filter.

After the analyzer warm up, with the vehicle engine at ON condition, the analyzer probe was inserted into the exhaust pipe tail end for detection and transmission of sampled exhaust gases. The 0 km filter was then subjected to exhaust analysis for duration of about three minutes. After the insertion of the 0 km filter, with the vehicle engine in ON condition, the operator (driver) was instructed to accelerate for fifteen seconds, and then allowed the engine to remain in an idle condition for prescribed period of 30 seconds by the test produce. The driver was asked to accelerate for another seven seconds and another 15 seconds of an idle period were observed. The exhaust gases were then transmitted continuously by probe to the analyzer for immediate analysis of each constitutes concentration.

During the emission test under the prescribed conditions, the HC and NO were measured in parts per million (ppm) while CO, CO_2 and O_2 were measured in percentage (%). In this test, the vehicle followed a prescribed driving procedure which includes acceleration, and deceleration at an engine speed of 2, 500 ± 100 rpm. A highly skilled operator was asked to operate the test vehicle. He strictly followed the test process by maintaining concentration, accelerating and decelerating in accordance with driving instruction as displayed on the monitor while the probe transmitted the exhaust gases.

After the completion the exhaust emission test on the 0 km filter, it was removed and replaced with the 50 km filter (with engine at OFF condition). The prescribed emission test procedure was then strictly followed as described above. The 150 km, 200 km and no filter exhaust emission test were also separately performed. The results of values obtained at idle and high speed from the emission tests are presented in tables and their respective corresponding graphs in the section 4.

3.2 Emission Test Results

Table 1: The New, Used and No Filters Average Emission Test Results at an Idle Speed

S/N	Exhaust Gas Constitutes	Filters					Total Average Emissions
		New	50 km	150 km	200 km	No	
1.	Hydrocarbons, HC (ppm)	268	294	269	358	258	1447
2.	Carbon monoxide, CO (%)	3	3	2	3	2	13
3.	Lambda	1	1	1	1	1	-
4.	Carbon dioxide, CO_2 (%)	12.5	12.5	12.5	12.5	13	63
5.	Nitric oxide, NO (ppm)	17	6	6	4	17	50

Table 2: The new, used and no filters average emission test results at high speed

S/N	Exhaust Gas Constitutes	Filters					Total Average Emissions
		New	50km	150km	200km	No	
1.	Hydrocarbons, HC (ppm)	288	292	282	286	266	1414
2.	Carbon monoxide, CO (%)	2.91	2.68	2.8	2.91	2.1	13.4
3.	Lambda	0.9	0.91	0.91	0.9	0.92	-
4.	Carbon dioxide, CO_2 (%)	12.5	12.5	12.5	12.5	12.5	62.5
5.	Nitric oxide, NO (ppm)	17	6	6	4	17	50

3.2.1 Hydrocarbon emissions

The corresponding graphs showing the result of average emission of HC (ppm) from new, used and no filter test at an idle and high speed are shown in Figure 3 and 4 respectively.

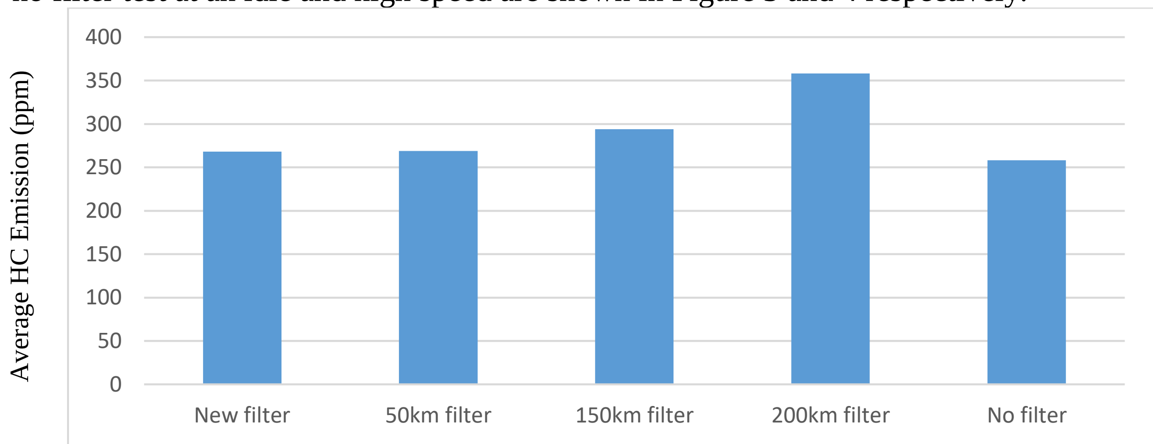

Figure 3: Average HC Emission from New, Used and No Filter Test at an Idle Speed

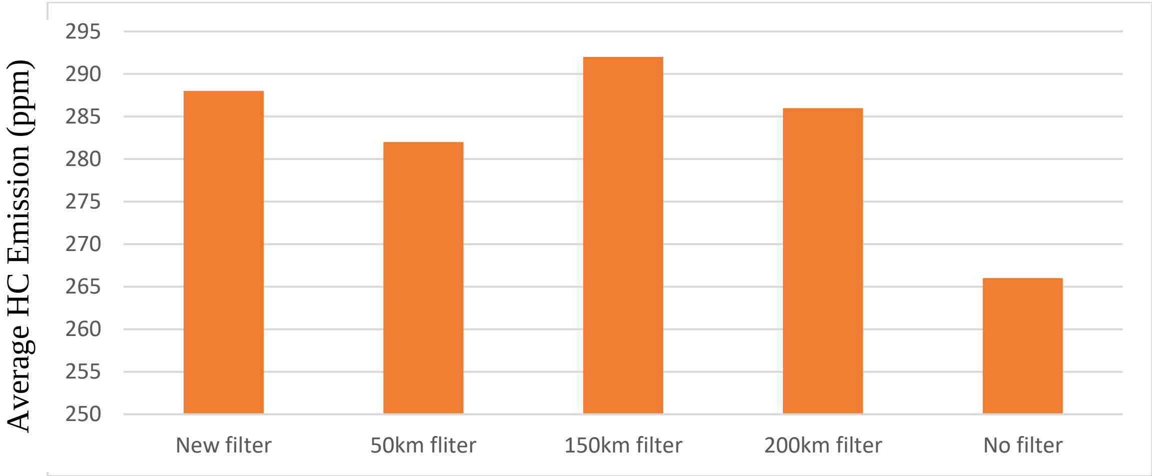

Figure 4: Average HC Emissions (ppm) from New, Used and No Filter Test at High Speed

Figure 3 shows that the average HC emissions from the 200 km filter was the major with 24.74% of the total average HC emissions. The average HC emissions from 150 km, 50 km, new and no filter were 20.32%, 18.59%, 1852% and 17.83% of the total average HC emissions respectively.

Figure 4 shows that the average HC emissions from new, used and no filters at high speed. The average HC emissions from the 150 km filter was the highest (20.65% of the total average HC emissions); it was followed by that of new filter (20.37%); then 200 km filter (20.23%) and 50 km filter (19.94%) respectively. The no filter average HC emission was the lowest with 18.81% of the total average HC emissions at high speed.

3.2.2. Carbon monoxide emission

The chart in Figures 5 and 6 show the results of average emissions from new, used and no filter test at idle and high speed respectively.

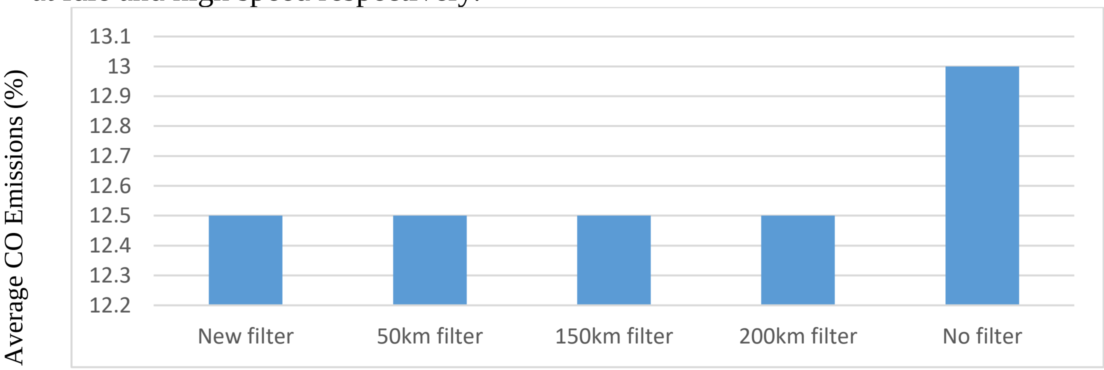

Figure 5: Average CO Emissions (%) from New, Used and No Filter Test at an Idle Speed

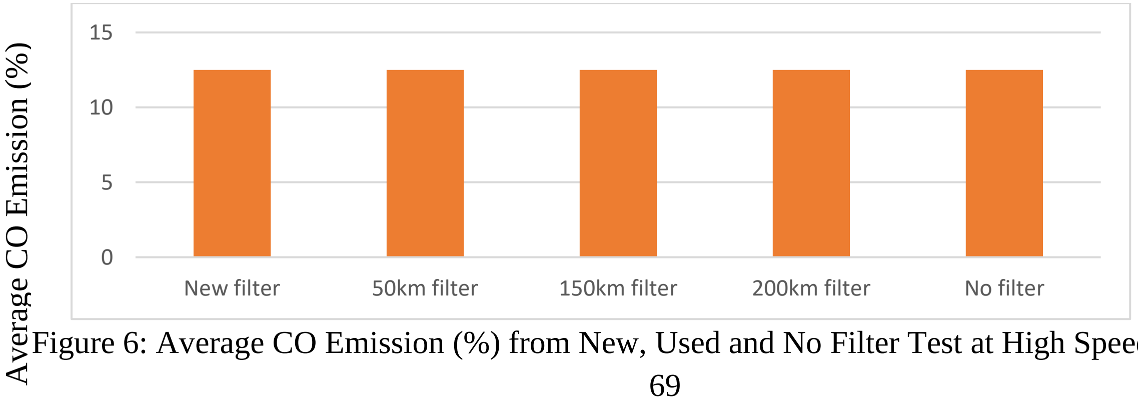

Figure 6: Average CO Emission (%) from New, Used and No Filter Test at High Speed

Figure 5 shows that the average CO emissions from the new, used and no filter test at an idle speed. The average CO emissions from the new, 50 km and 200 km filters were the same (23.08% of the total average CO emissions). The 150 km and no filter wore also the same (15.38% of the average total CO emissions).
Figure 6 shows that, the average CO emissions from the new and 200 km filters were the highest which amount to 21.72% of the CO total average emissions at high speed. The CO emissions from 50 km, 150 km and no filers test were 20%, 20.00% and 15.67% respectively.

3.2.3. Lambda parameter

The graphs in Figures 7 and 8 show the results of Lambda at an idle and high speed for the new, used and no filters emission test.

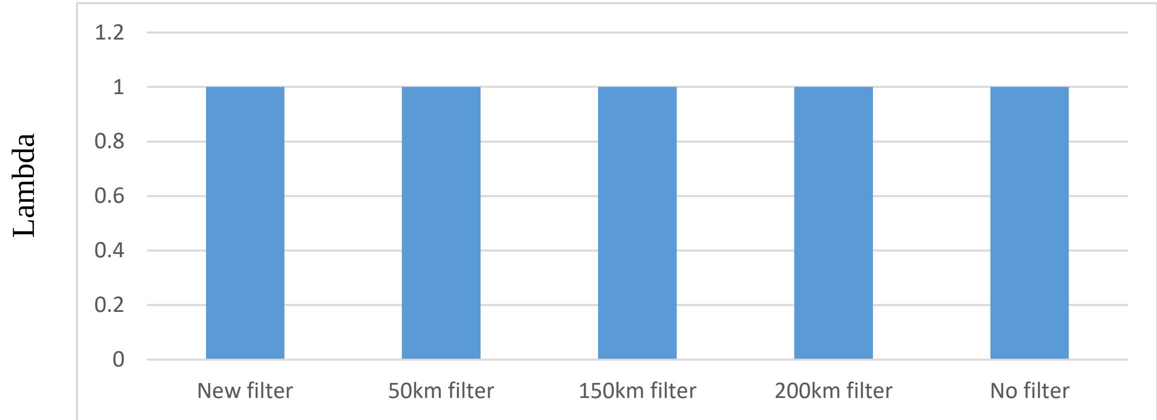

Figure 7: Lambda Parameters for the New, Used and No Filter Emission Test at an Idle Speed

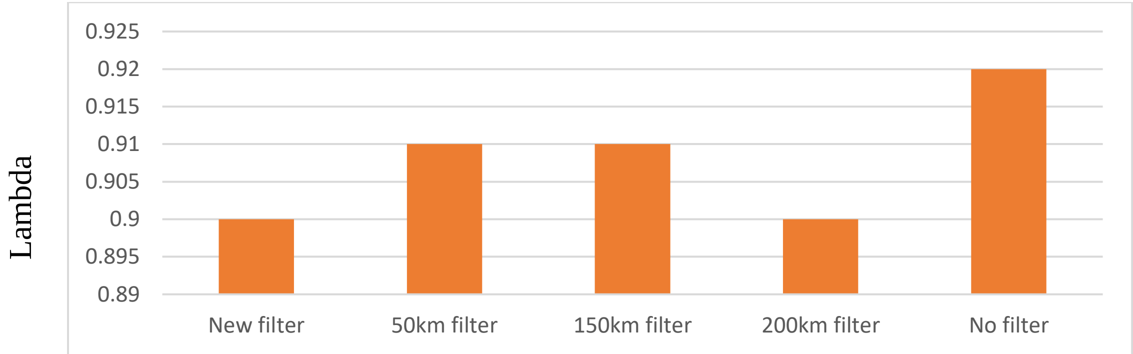

Figure 8: Lambda Parameters for the New, Used and No Filter Emission Test at high Speed

Figure 7 shows that Lambda had a constant value of one (1) for the new, used and no filter test at an idle speed. However, at high speed emission test carried out, the result in Figure 8 indicates slight variation of Lambda parameter.

3.2.4 Carbon dioxide emission

The charts in Figures 9 and 10 show the result of average CO_2 emission from new, used and no filter test at an idle and high speed.

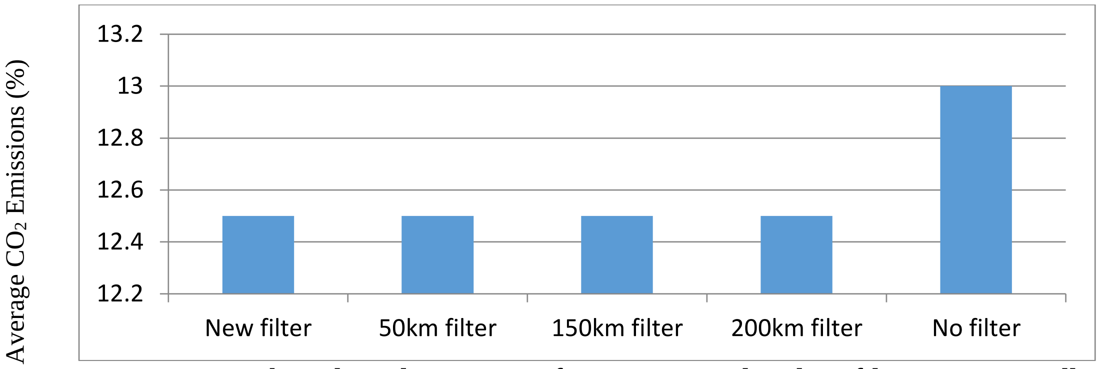

Figure 9: Average Carbon dioxide emission from new, used and no filter test at an idle speed

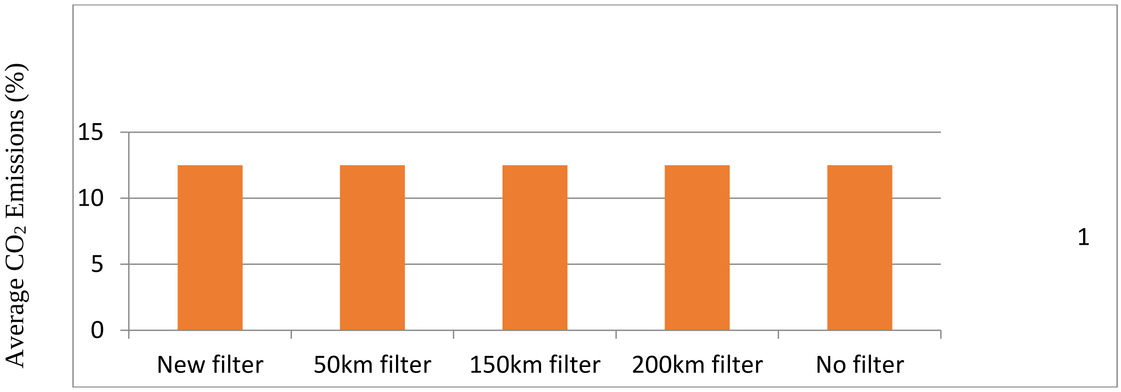

Figure 10: Average CO_2 emissions from new, used and no filter test at high speed

Figure 9 shows that the average CO_2 emissions from the new, 50 km, 150 km and 200 km filter were the same (12.5%); while the average CO_2 emission of the no filter test carried out was highest (13%). Figure 3.4 (b) shows that the average CO_2 emission from the new, used and no filter test at high speed were all equal (12.5%).

3.2.5. Nitric oxide emission

The chart in Figure 11 shows the results of the average NO emissions (ppm) from new, used and no filter test at an idle speed

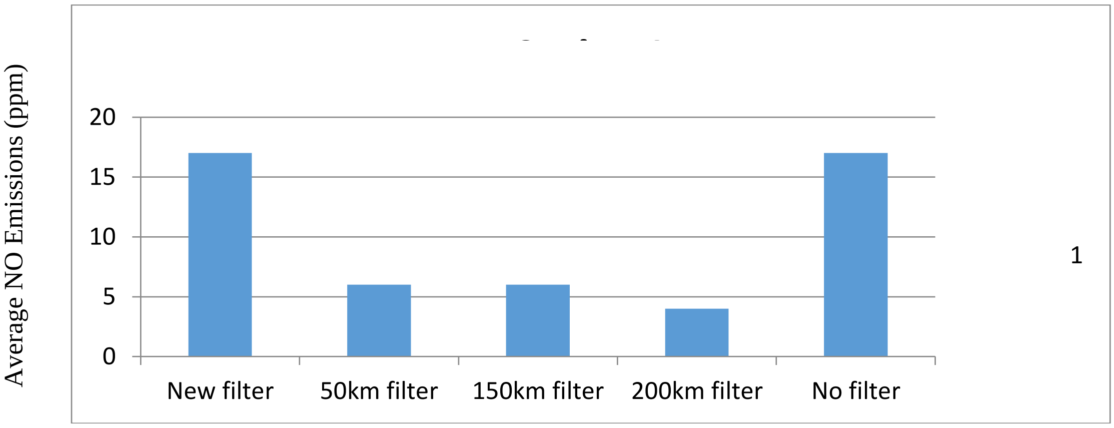

Figure 11: Average Nitric oxide emission from new, used and no filter test at an idle speed.

The result shows that the average NO emissions from the new and no filter test were the major (17 ppm). The average NO emissions from 50 km and 150 km filters was the same (6 ppm) while the 200 km filter had the lowest amount of average NO emission (4 ppm). The above average NO emission result (as shown in figure 4.6) from new, used and no filter test were the same with the averages NO emission at high speed.

4. Results Discussion

The exhaust gases emission results are discussed here. The emissions were estimated by the use of 5-way emission analyzer using a four stroke SI gasoline 2008 model Peugeot 406 as a test vehicle. In this study catalytic converter efficiency was taken as same for the new, used and no filters test carried out at an idle and high speed.

4.1 Hydrocarbons emission

Figures 3 and 4 show the results of the average HC (ppm) emissions (unburned gasoline) from the new, used and no filter tests at an idle and high speed. Figure 3.1 (a) shows that the average HC emissions by no filter test were the lowest (17.83% of total average HC emissions) and average HC emissions by 200 km filter test was the highest (24.74%). However, there was a gradual increase from new filter test (18.52%) to 18.59% (50 km filter test), then 20.32% (150 km filter test) before reaching its peak at 200 km filter test.

Similar pattern was shown in Figure 4, where the average HC emission by no filter test was lowest (18.81% of total average HC emissions); and there was a gradual increase in average HC emissions from the used filters as the distance plies by test vehicle increases. Thus, HC emissions increased may be due to filter clogging by dust (2).

4.2 The carbon monoxide emissions

Figures 5 and 6 show the results of average CO emissions from the new, used and no filter tests at an idle and high speed. The figures show clearly that used filters emit more carbon monoxide than the no filter condition. The results indicate gradual increase in average CO emission at both idle and high speed for the used filters. For instance, in Figure 6, the average CO emissions was lowest for 50 km filter test (20%), and then, increases steadily as the distance coverage was increased to 200 km (21.72%). A study on effect of air intake pressure to the fuel economy and exhaust emission os SI gasoline engine show that high air intake systems result in better fuel combustion and lead to less reduction of unburned carbon monoxide. This increase in average CO emissions with distance plies on the road may be due to incomplete combustion inside the engine (2, 6, 7, 8, and 10).

4.3 Lambda parameter

Lambda is a parameter that gives the amount of air in relation to fuel that goes into the combustion chamber. It states clearly if the combustion chamber has more fuel than air (i.e. rich mixture) or more air than fuel (i.e. lean mixture). If lambda is less than or equal to 1; it represents a rich mixture while lambda value greater than one (1) represents a lean mixture.

Figures 7 and 8 indicate that the air and fuel mixtures that were used in the combustion were rich. However, there was slight variation in lambda reading at high speed. If filters blockage (by dust) increases with distance plies on the road (as expected), the amount of oxygen that would be available for combustion would be expected to decrease, thereby causing the mixture to be richer. This indicates that lambda reading is expected to reduce with more distance plies on dusty tarred roads.

4.4 The carbon dioxide emission

Figures 9 and 10 show that the results of the average CO_2 emissions from the new, used and no filter tests at an idle and high speed. Figure 9 show that the average CO_2 emissions from the no filter test (13%) was higher than the equal value (12%) obtained for the new and used filters. This indicates that the combustion was more efficient during the no filter test at an idle speed when compared to:

i. The new and used filters tests at idle speed.
ii. The new, used and no filter tests at high speed as shown in Figure 10.

Studies have shown that CO2 emission is higher in without air filter condition when compared to the with air filter condition as more complete combustion produce more CO2 due to the availability of more oxygen to combine with the fuel carbon [2, 3, 5, 6, 7, 8, 9, 10 and 11]. Thus, the 1% difference between without air filter and with air filter may be due to more availability of oxygen in no filter during the combustion process in the cylinder.

4.5 Nitric oxide emissions

Figure 11 shows the result of the average NO emissions from the new, used and no filter tests at an idle and high speed. The result indicates that the average NO emissions, (product of nitrogen during the combustion in the cylinder) as the same at both and idle and high speed. However, the results indicate that the highest and lowest average NO emissions were 17 ppm (new and no filter tests) and 4 ppm (200 km filter test). This shows that increased air filter clogging makes a less efficient combustion process and reduces the number of NO formations [2]. Therefore, the higher air intake pressure and temperature in the new and no filter tests increased the NO formations while the same value of 17 ppm may be due to the possibility of some combustion temperature in the cylinder during the tests.

5. Conclusion and recommendations

5.1 Conclusion

The results show that the increased air filter clogging with distance plies on dusty tarred causes more emissions of average hydrocarbons and carbon monoxides to the atmosphere at both idle and high speed. However, at both idle and high speed, emission tests results show that average CO_2 and NO formation decreases as distance plies by test vehicle increases. The results clearly indicate that increased air filter clogging reduces NO and CO_2 emission due to less efficient combustion process as result of decreased air inflow into the engine.

5.2 Recommendations

i. The cleaner the air that goes into the filter the better the effectiveness of such filter, engine performance and emission. 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. Nigeria may require legislation with regard to vehicular emissions. However, more detailed research covering different vehicle categories and fuels should be carried out and Nigerians sensitized before imposing any such emission directives.

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