Environmental Impact of Increased Consumption of Engine Oil in the Combustion Chamber of a Spark Ignited Engine

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Abstract: Blue smoke is a classic sign of oil consumption in the engine and the major causes of these emissions are found to be worn-out piston rings, valve seals and valve guides. These causes are the resultant effect of increased oil consumption in the internal combustion engine, leading to excessive release of harmful exhaust emissions. This study is aimed at looking at the environmental impact of such increased oil consumption, by collecting exhaust samples from some vehicles that have oil consumption problems, using the Exhaust Gas Analyzer. Thereafter the pollutants are analyzed and estimated to determine their concentration and consequential impact on the environment. The result obtained showed that excessive engine oil consumed in the combustion chamber of the spark ignited engine can lead to high concentration of pollutants (NOx, CO, CxHy) released into the environment.

Key words: Blue smoke, exhaust gas analyzer, oil consumption

INTRODUCTION

Engine oil consumption is a problem nobody wants. Most new engines today use less than half a quart of oil in 3,000 miles. Some use almost no oil. But as the miles accumulate, wear and oil consumption naturally go up. Using a quart of oil every 1,000 miles is not unusual for a high mileage engine. The amount of oil used is still acceptable, but by the time it reaches a quart or more in 500 miles it's using a lot of oil. Blue smoke is a classic sign that an engine is burning oil (Bernd et al., 2004).

An engine that burns oil will usually foul the spark plugs. That, in turn, will cause ignition misfire, higher emissions and likely damage the catalytic converter (Ajayi and Dosunmu, 2002). Also, an engine that is burning oil usually won't pass an emissions test because of elevated emissions of unburned hydrocarbon (HC) and carbon monoxide (CO).

The engine oil, depending on its viscosity (5W-30 to a 10W-30 or a 10W-40) is one of the most important fluids in an internal combustion engine. Without oil the engine cannot operate properly as the oil is responsible for minimizing friction between metallic surfaces (Bernd et al., 2004). This is achieved by means of a lubricating film which is generated between the moving parts of the engine during operation.

The engine oil also plays the role of preventing corrosion and sludge deposits; aggressive substances are generated during the combustion process, which are then neutralized by the lubricating oil. More so the oil cools down the engine once it has reached its operating temperature, thus preventing overheating of the engine. However, if the engine oil escapes into the combustion chamber of the internal combustion engine as a result of worn-out rings, valve seals, valve guides and cylinder bore, it will be burnt with the air/fuel mixture thereby resulting in the excessive release of harmful exhaust emissions (De Petris et al., 1996). This is because all the carbon atoms are not oxidized during the combustion processes, resulting in incomplete combustion. This study examines the environmental impact of oil consumption in the combusting chamber.

Oil consumption mechanisms: Three different mechanisms of oil consumption occur in the ring-pack system. Oil evaporates from the worn rings and cylinder liner into the combustion chamber, oil is thrown off from the ring due to inertia, and gas blowing back towards the combustion chamber entrains oil from the ring pack. In all cases, the oil escapes from the cylinder with the exhaust gases.

The evaporated oil trails behind or passes between the top ring and the liner during the downstroke. The amount of oil left behind on the liner is dependent on the scraping effect of the rings (Gulwadi, 2000). De petris and Co-workers point out that reverse blow-by, meaning gas flow from the crankcase to the combustion chamber during the exhaust phase, is one of the most significant means by which the oil is transported into the combustion chamber (De Petris et al., 1996).
During the upstroke, the ring-pack lubrication is dependent of the oil film left on the cylinder liner during the downstroke. The top ring scrapes oil off the liner, and the oil is accumulated in front of the top ring. This accumulated amount of oil is thrown off the ring at TDC (Top Dead Centre) due to inertial (Gulwadi, 2000). Throughout the engine cycle, oil is present in the ring pack area. This oil becomes entrained in the gases flowing to and from the combustion chamber. This entrained oil comes from accumulated oil at the ring-end gaps and the leading and trailing edges of the rings, from oil on the liner surface, and from oil on the groove surfaces (Ariga, 1996). Since environmental demands are becoming even stricter regarding the exhaust emissions of internal combustion engines, the oil flow into the combustion chamber has to be reduced.

The combustion chemistry of fuel and oil in the combustion chamber: The complete (stoichiometric) combustion of fuel in a pure oxygen environment (without oil mixing with fuel) is expressed as (Kenneth, 2005):

\[
C_xH_y + \left[ x + \frac{y}{4} \right]O_2 \rightarrow xCO_2 + \left[ \frac{y}{2} \right]H_2O
\]  

(1)

where the reactants; \(C_xH_y\) and \(O_2\) represent Fuel and Air that is burned in the combustion chamber, while the Products \(CO_2\) and \(H_2O\) is the Carbon Dioxide and Water released from the exhaust after combustion.

The chemical equation for the three major constituents of fuel drawn from Eq. (1) will now be given as (Osei, 2005):

\[
2C_6H_{14} + 21O_2 \rightarrow 12CO_2 + 14H_2O + Heat \]
\[
2C_8H_{16} + 22O_2 \rightarrow 14CO_2 + 16H_2O + Heat \]
\[
2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O + Heat
\]  

(2)

The incomplete combustion of fuel in an oxygen starved environment as a result of engine oil mixing with fuel (rich mixture) will be (Kenneth, 2005):

\[
(x)C_xH_y + \left[ z \left( \frac{x}{2} + \frac{y}{4} \right) \right]O_2 + HC
\]

\[
\rightarrow zxCO + (x, y / 2)H_2O + HC
\]  

(3)

where the reactants; \(C_xH_y, O_2, \) and \(HC\) represents the Fuel, Air and Engine Oil in the combustion chamber while the products \(CO, H_2O\) and \(HC\) represents Carbon Monoxide, Water and Unburned Hydrocarbons (HC) from the engine exhaust.

The chemical equation for an incomplete combustion drawn from Eq. (2) above will be:

\[2C_6H_{14} + 13O_2 + HC \rightarrow 12CO + 14H_2O + HC + Heat;\]
\[2C_8H_{16} + 15O_2 + HC \rightarrow 14CO + 16H_2O + HC + Heat;\]
\[2C_8H_{18} + 17O_2 + HC \rightarrow 16CO + 18H_2O + HC + Heat;\]  

(4)

The engine oil (Hydrocarbon) present during combustion does not burn completely with the fuel because:

- Engine oil is not a volatile hydrocarbon
- It is not easily oxidized, unlike fuel which is easily oxidized
- The ignition temperature of engine oil is far much higher than that of motor fuel (Osei, 2005)

The end result of this incomplete combustion is the excessive release of \(CO, C, CO_2\) and Unburned Hydrocarbons (HC) from the engine exhaust.

**METHODOLOGY**

In this study, both theoretical and experimental methods of modeling exhaust emissions were carried out to determine its concentration. The theoretical method was carried out by assuming certain values for the amount of engine oil consumed at different rates, while the experimental method was carried out by measurements; the reason for this is to allow for easy computation of these pollutants when the need arises.

In the experimental method, certain vehicles whose engines consume oil at different rates and time were investigated and sampled for data collection. The data collection took place in some parts of Edo and Delta states of Nigeria at various times of the day, for three consecutive days. Readings were carried out between the hours of 8 am and 4 pm daily from a number of vehicles with various degrees of oil consumption to ascertain the concentration of pollutants released. The data collected were obtained from the vehicle exhaust using the probe of the “Exhaust Gas Analyzer” with Model number “Testo 350 XL”. To determine the estimated value of the pollutants, the result of the exhaust readings was analyzed and modeled using linear and quadratic fitting of the MATLAB Code.

**RESULTS**

The mathematical model and graphical representation of the estimated value of these pollutants with respect to increased oil consumption are given as:

\[
CO = \begin{cases} 
40k + 1400 & \text{if } 0.1 \leq k \leq 0.2 \\
7800k - 120 & \text{if } 0.2 < k \leq 0.3 \\
1200k + 1900 & \text{if } 0.3 < k \leq 0.4 \\
19000k - 5200 & \text{if } 0.4 < k \leq 0.5 
\end{cases}
\]  

(5)
Fig. 1: Plots of estimated and measured values of carbon monoxide emissions against engine oil consumed.

Fig. 2: Plots of estimated and measured values of hydrocarbon emissions against engine oil consumed.

\[ C_{\text{CO}} = \begin{cases} 
0.8x + 1400 & \text{if } 0.1 \leq k \leq 0.4 \\
160x - 120 & \text{if } 0.4 < k \leq 0.5 \\
24x + 1900 & \text{if } 0.5 < k \leq 0.6 \\
380x - 5200 & \text{if } 0.6 < k \leq 0.7 \\
\end{cases} \]

\[ C_{\text{CxHy}} = \begin{cases} 
-3100k^2 + 12000k - 320 & \text{if } 0.1 \leq k \leq 0.4 \\
63000 - 21000k & \text{if } 0.4 < k \leq 0.5 \\
-1.2x^2 + 250x - 320 & \text{if } 5 \leq x \leq 20 \\
1300x - 21000 & \text{if } 20 < x \leq 25 \\
\end{cases} \]

where, 'k' is the amount of engine oil consumed in quart, CO (Carbon Monoxide), and CxHy (Hydrocarbon) are the pollutants released into the environment in Parts Per Million (ppm); while the estimated values of pollutants with respect to “Number of years the vehicle was used” are given as:

\[ C_{\text{CO}} = \begin{cases} 
0.8x + 1400 & \text{if } x \leq 10 \\
160x - 120 & \text{if } 10 < x \leq 15 \\
24x + 1900 & \text{if } 15 < x \leq 20 \\
380x - 5200 & \text{if } 20 < x \leq 25 \\
\end{cases} \]
(ii) the number of years the vehicle was used. The results of the mathematical models for these variables compared favourably with similar results obtained by measurements as seen in Fig. 1 and 3 of Eq. (5) and (7) and Fig. 2 and 4 of Eq. (6) and (8). For ease of computation, any of the variables could be used to estimate the amount of pollutants released from the exhaust vehicle as oil consumption increases.

Figure 1 shows that, the amount of Carbon Monoxide emissions released into the environment remained constant at 1442 ppm when the value of engine oil consumed increased only marginally from 0.1-0.2 quart. This indicates that the amount of rich fuel/air mixture present in the combustion chamber at that point is still within acceptable limits in the internal combustion engine and so could not trigger further release of CO at that point.

Fig. 3: Plots of estimated and measured values of carbon monoxide (CO) emissions against the number of years the vehicle was used

Fig. 4: Graph of estimated and measured values of hydrocarbon (C\textsubscript{X}H\textsubscript{Y}) emissions against the number of years the vehicle was used

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>1 h mean ((\mu)g/m(^3))</th>
<th>8 h mean ((\mu)g/m(^3))</th>
<th>Daily average Mean ((\mu)g/m(^3))</th>
<th>Annual mean ((\mu)g/m(^3))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspended Particulate Matter (SPM)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black Smoke</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (SPM)</td>
<td>150-230</td>
<td>60-90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon</td>
<td>30</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monoxide (CO)</td>
<td>26.09 ppm</td>
<td>8.70 ppm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulphur</td>
<td>350</td>
<td>100-150</td>
<td>40-60</td>
<td></td>
</tr>
<tr>
<td>Dioxide (SO\textsubscript{X})</td>
<td>0.14 ppm</td>
<td>0.04-0.06 ppm</td>
<td>0.016-0.24 ppm</td>
<td></td>
</tr>
<tr>
<td>Nitrogen</td>
<td>400</td>
<td>150</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dioxide (NO\textsubscript{X})</td>
<td>0.02 ppm</td>
<td>0.08 ppm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead</td>
<td></td>
<td></td>
<td></td>
<td>0.5-1.0</td>
</tr>
</tbody>
</table>

Table 1: National air quality guidelines for maximum exposure (Egaspin, 2002)
range. However, when the value of engine oil consumed rose from 0.2-0.5 quart, the value of the pollutant (CO) was increased drastically from 1442-4228 ppm. Figure 2 shows a step rise of Hydrocarbon pollutant from 890-3132 ppm as the oil rose from 0.1-0.4 quart but later increased sharply when the amount of engine oil increased to 0.5 quart.

The graphs of Fig. 1, 2, 3 and 4, clearly indicate the output of an incomplete combustion taking place in a spark ignited engine, as seen in Eq. (4). It indicates how an increased consumption of engine oil would result in the rise of pollutants. These values of pollutants are very high when compared to the emission values established by the FEPA (Federal Environmental Protection Agency, 1991) and EGASPIN (Environmental Guidelines and Standards for the Petroleum Industry in Nigeria). This seems to indicate that the environment is not safe and that the climate may be adversely affected (Table 1).

**CONCLUSION**

From this study, we have been able to show that excessive engine oil consumed in the combustion chamber of the spark ignited engine can lead to high concentration of pollutants (NOx, CO, CxHy) released into the environment. These pollutants are capable of causing harm to the environment by contributing to the formation of smog, ground level ozone, global warming, headache, heart pain, eye irritation, cough, and drowsiness. This study suggest that vehicle and stationary engine owners should be cautious of oil consumption and make sure that measures are put in place to reduce it.

**REFERENCES**


