INVESTIGATION OF THE EFFECT ON ENGINE PERFORMANCE OF USING HIGHER OCTANE RATING GASOLINE THAN ENGINE REQUIREMENT

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Abstract: The effect of using higher-octane gasoline than engine requirement on power and fuel economy is revealed. In this study, the engine required 91-RON gasoline was tested using 95-RON and 91-RON. Results show that using octane ratings higher than required by the vehicle engine numbers don’t increase engine performance.

Key words: Gasoline engine, octane number, gasoline fuel, engine performance.

1. Introduction

Refiners and automotive manufacturers are interested in the octane number requirement of engines or vehicles on the road. The octane number requirement of an engine or vehicles-engine combination is defined as the minimum fuel octane number that will resist knock throughout the engine’s operating speed and load range. The octane number requirement of single engine or vehicle does not usually provide adequate information for that particular model; every model has a range of requirements due to production tolerances and variations in engine and vehicle condition [1].

Liquid hydrocarbons and rarely alcohols are used for in the internal combustion engine. Gasoline quality is indicated by octane rating. The engine design and compression ratio determine the octane it requires. However, this requirement changes with weather, driving conditions, and mechanical condition of the engine. For example combustion-chamber deposits reduce clearance volume. They also increase octane requirements and the possibility of detonation. Reduced cooling efficiency, fuel system or ignition troubles, and failure of emission controls may also change octane requirements. Octane requirement will be lower if the driver does not demand rapid acceleration and high-speed wide-open throttle [2].

In practice, motorists have strong believes that higher octane rating, better engine performance and fuel economy. This leads to popular use of higher-octane gasoline than engines requirement and causes extra expense to produce
high-octane fuel. Although campaign to use corrected gasoline grades has been launched through televisions, radios, and newspaper for period of time, the amount of high-octane gasoline sold still greater than expectation. It is expected that further information including test results of using higher-octane gasoline than engine requirement will clarify to motorists concerning their misconception and believes [3].

Various investigations clearly reported that octane number is effect on engine performance. In 1991 Coordinate Research Council (CRC) was studied the effect of gasoline octane quality on vehicles acceleration performance. There were 182 gasoline vehicles involved in the test. 78 vehicles were installed by knock sensor and 104 vehicles without knock sensor. Gasoline with 80-104 RON were included and each vehicle was tested with 4 gasoline grades, i.e. fuel with 4 RON less than engine required, fuel with the same RON as engine required, fuel with 4 and 8 RON greater than engine required. Testing method involved recording of the vehicle acceleration time from 0-48, 0-96, 0-112 and 64-96 km/h. Results show that acceleration performance of KS vehicles was improved with gasoline octane quality while acceleration performance of the vehicles without knock sensor was insignificant relation with gasoline octane rating [4].

In 1998 the effect of gasoline octane number on engine performance was studied in Thailand. Three different octave ratings of 91, 95 and 97-RON were investigated in three engine models that all required 95 RON. These engines were used in Toyota Corolla. The engine models were 5A-FE, 4A-FE, 7A-FE with engine displacements of 1.5, 1.6 and 1.8 l, respectively. Test runs were conducted at two throttle settings of 50 % WOT and 100 WOT and a range of engine speeds. Results show that at a given throttle position engine power insignificantly change with octane number for all engines [5].

2. Theoretical Analysis of Experimental Instrumentation

After each experimental run, raw data consisting of pressure drop reading in mm of water column from the manometer is recorded. From this raw data, mass flow rate, Reynolds numbers are calculated.

2.1.1 Mass Flow Rate

Mass flow rate has been measured by means of an orifice plate. The operating principle of orifice plates is based on relation between the velocity and pressure of a flowing fluid. When a restriction, such as small diameter orifice plate, is inserted in a stream, fluid velocity must increase when passing through it. A proportional drop in pressure based on Bernoulli’s equation accompanies the rise in velocity.

Mass flow rate through the PVC pipe is calculated by the following expressions given by ASME standards [6].

\[
m = \frac{C \varepsilon \pi d^2}{4} \left( \frac{2 \rho_a \Delta P}{1 - \Phi^4} \right)
\]

(1)

where \( \varepsilon \) is the expansion factor, which can be assumed as the unity under our experimental conditions, \( d \) is the orifice plate diameter, \( \Phi \) is the orifice plate diameter ratio, \( \rho_a \) is the density air, \( \Delta P \) is the pressure drop across the orifice plate, and \( C \) is the charge coefficient expressed according to ASME standards [6] as;
\[ C = 0.5959 + 0.0312\Phi^{2.1} + 0.1840\Phi^8 + 0.039\Phi^4(1 - \Phi^4)^{-1} - 0.01584\Phi^3 + 91.71\Phi^{2.5} \left[ \text{Re}_p \right]^{-3/2} \]  

(2)

The Reynolds number, \( \text{Re}_p \), in the PVC pipe is then calculated as:

\[ \text{Re}_p = \frac{4m}{\pi \mu D_p} \]  

(3)

where \( \mu \) is the viscosity of air, \( D_p \) the PVC pipe diameter.

2.1.2 Fuel Mass Flow Rate

Fuel mass flow rate has been measured by means of scaled container, which depends on time shown in the equation below.

\[ m_f = \frac{\rho_f V_f}{t} \]  

(4)

where \( \rho_f \) is the density of fuel, \( V_f \) is the volume of consumed fuel, \( t \) is fuel consumption period.

2.1.3 Specific Fuel Consumption Rate

Specific fuel consumption related to effective power and fuel mass rate as shown in the equation below:

\[ bsfc = 3.6 \times 10^6 \frac{m_f}{Pe} \]  

(5)

where \( m_f \) is fuel mass flow rate and \( Pe \) is effective power, which directly obtained from a digital dynamometer.

2.1.4 Experimental Uncertainties

The uncertainty associated with the mass flow rate was affected by all of the parameters in the experiments, such as pressure drop across the orifice plate, the calculations of all factors and coefficients and the thermal properties of the working fluid. The maximum value of the uncertainty in the mass flow rate was found as ±1.03 % and ±2.63 % for laminar and turbulent flows [6].

3. Experimental Facilities

Engine used in the test was a Fiat DKS 1,6 l. The engine originally requires gasoline fuel with 91-RON. Details of engine specification are shown in table 1.
Table 1. The technical specifications of the experimental engine.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine type</td>
<td>131 A 1016</td>
</tr>
<tr>
<td>Cylinder number</td>
<td>4</td>
</tr>
<tr>
<td>Cylinder bore</td>
<td>84 mm</td>
</tr>
<tr>
<td>Stroke</td>
<td>71.5 mm</td>
</tr>
<tr>
<td>Total cylinder vol.</td>
<td>1600 cc</td>
</tr>
<tr>
<td>Compression ratio</td>
<td>8:1</td>
</tr>
<tr>
<td>Maximum torque</td>
<td>117.2 Nm/3400 rpm</td>
</tr>
<tr>
<td>Maximum power</td>
<td>58.88 kW</td>
</tr>
<tr>
<td>Value of valve adjustment</td>
<td>Cold (+20 °C): Intake: 0, 30 Exhaust: 0, 45</td>
</tr>
</tbody>
</table>

Fuel was commercial grades with 91 and 95-RON. Details of fuel compositions and properties in table 2.

Table 2. Properties of test fuel.

<table>
<thead>
<tr>
<th>Property</th>
<th>91</th>
<th>95</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density at 15 °C, kg/l</td>
<td>0.738</td>
<td>0.745</td>
</tr>
<tr>
<td>Reid vapour pressure, kPa</td>
<td>59.34</td>
<td>60.03</td>
</tr>
<tr>
<td>Boiling temperature, °C</td>
<td>198.9</td>
<td>209</td>
</tr>
<tr>
<td>Lower heating value, kJ/kg</td>
<td>43932</td>
<td>43304</td>
</tr>
<tr>
<td>Benzene, % volume</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Pressure drop is determined by inclined manometer. Engine load is measured by a dynamometer. Fuel consumption is quantified by combined container method and air ratio is determined by orifice-meter. Cylinder pressure data were recorded using 6061 B piezoelectric pressure transducer. The experimental apparatus is shown in figure 1.

Figure 1. Experimental apparatus
4. Test Procedure

All test runs were conducted on the bench-test. In each test run, engine speed, torque, fuel consumption, throttle position were recorded. Moreover, for detail analysis of consumption process, cylinder pressure time, data for a resolution of one degree crank angle were recorded for 300 consecutive cycles. The combination of all performance tests included engine setting at throttle position of 50 % and 100 % WOT, engine speeds 1000-2400 rpm with 200 rpm intervals and engine torque of 20 %-90% of maximum value. For cylinder pressure data collection, the engine were set at 25 % and 35 % WOT and speeds of 1400-2400 rpm.

5. Results and Discussions

To compare output power of the engine when fuel with 91-RON and 95-RON gasoline, the engine was tested at 50 % and 100 % throttle opening and speeds were varied from 1000-2400 rpm. The results of output power were shown in figure 2-3. Power output of 91-RON at 50 % WOT and 100 % WOT are slightly greater than that of 95-RON for a range testing as shown in figure 1 and 2. At 50 % WOT, average power produced from 91-RON gasoline is 4.8 % greater than 95-RON while at 100 % WOT the benefit of power is about 4.2 %.

If it is used higher octane rating gasoline more than engine requirement, the ignition delay will be longer and the speed of the flame will be shorter. Therefore longer time is needed to reach maximum combustion pressure and this maximum pressure occur 10⁹ (CA) after TDC. These cause the reduction of the maximum pressure and the engine output power [7].

Figure 2. Engine power at various speeds (50 % WOT)

Figure 3. Engine power at various speeds (100 % WOT)

To compare bsfc when the engine was operated with 91 and 95-RON gasoline, the engine was tested at fixed speed and load for several test conditions. The test results at 1500 rpm are shown in figure 4. It can be seen that the trend of bsfc using 91-RON is slightly lower and average bsfc using 91-RON is 5.6 % better than that of 95-RON.
To study details of combustion process in the cylinders when 91 and 95-RON gasoline were used, the cylinder pressure-time data for 300 consecutive cycles were recorded at operating conditions. The combinations of test conditions were set at speeds of 2500 and 3500 rpm and throttle positions of 25 % and 35 % WOT. The Results of analysis are shown in Table 3. The values of $P_{\text{max}}$ using 91-RON gasoline slightly greater than that using 95-RON. It shown that lower-octane rating gasoline produces higher peak cylinder produces.

Table 3. Results of engine test and cylinder pressure analysis.

<table>
<thead>
<tr>
<th>Items</th>
<th>2500 rpm</th>
<th>3500 rpm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25 % WOT</td>
<td>35 % WOT</td>
</tr>
<tr>
<td>Octane no</td>
<td>91</td>
<td>95</td>
</tr>
<tr>
<td>$P_{\text{max}}$ (bar)</td>
<td>35.92</td>
<td>35.07</td>
</tr>
</tbody>
</table>

From the above test results of power output, bsfc and cylinder pressure data analysis, they all confirm that lower-octane gasoline produces slightly better power and fuel economy.

6. Conclusions

The effect of using higher-octane gasoline than engine requirement on power output and fuel economy was studied. The engine required was tested with 91-RON and 95-RON fuel.

When the engine was tested at given throttle position and speed, results show that 91-RON gasoline produced 4.2-4.8 higher power than 95-RON. When the engine was set at given speed and torque, it was shown that 91-RON gasoline produced 8.36 lower bsfc than 95-RON. Results from the cylinder pressure analysis also confirm the performance test results.

Therefore using corrected rating gasoline is more advantageous than higher-octane gasoline under all operating conditions.
7. Nomenclature

- \( m \) Mass flows rate, kg/s
- \( m_f \) Fuel mass flow rate, kg/s
- \( d \) Diameter of the orifice plate, m
- \( D_p \) Diameter of PVC pipe, m
- \( \text{Re}_p \) Reynolds number in the PVC pipe
- \( \varepsilon \) Expansion factor
- \( \Phi \) Orifice plate diameter ratio, \( d/D_p \)
- \( \rho_a \) Air density, kg/m\(^3\)
- \( \rho_f \) Fuel density, kg/m\(^3\)
- \( \text{Pe} \) Effective power, kW
- \( \mu \) Dynamic viscosity
- \( \Delta P \) Pressure drop across the orifice plate, Pa
- \( V_f \) Volume of consumed fuel, m\(^3\)
- \( t \) Fuel consumption period

8. Abbreviations

- RON Research octane number
- WOT Wide open throttle
- rpm Revolution per minute
- bsfc Specific fuel consumption, gr/kWh

References