EXPERIMENTAL STUDY ON PERFORMANCE AND EMISSION CHARACTERISTICS OF ACETONE – GASOLINE MIXTURE IN SI ENGINE

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Abstract—In this study, new blended fuels were formed by adding 3–9 vol. % of acetone into a regular gasoline. According to the best of the author’s knowledge, it is the first time that the influence of acetone blends has been studied in a gasoline-fueled engine. The blended fuels were tested for their energy efficiencies and pollutant emissions using SI (spark-ignition) engine with Three-cylinder and 4-stroke. Experimental results showed that the AC3 (3 vol.% acetone + 97 vol.% gasoline) blended fuel has an advantage over the neat gasoline. As the acetone content increases in the blends, as the engine performance improved where the best performance obtained in this study at the blended fuel of AC9, compared to neat gasoline. In addition, the use of acetone with gasoline fuel reduces exhaust emissions averagely by about 43% for carbon monoxide, 32% for carbon dioxide and 33% for the unburnt hydrocarbons. Eenhanced engine performance and pollutant emissions are attributed to the higher oxygen content, slight leaning effect, lower knock tendency and high flame speeds of acetone, compared to the neat gasoline.

I. INTRODUCTION

During the past few decades, an increased consumption of fossil fuels by the transportation industry has exacerbated the oil crisis and environment problems. Among various environment pollutants, automobile exhaust is one of major sources of atmospheric pollution. Typically, regulated emissions such as particulate matter (PM), nitrogen oxide (NOx), Sulphur dioxide (SO2), carbon monoxide (CO) and unregulated emissions such as polycyclic aromatic hydrocarbons (PAHs), aldehydes, acids are the main components in vehicle exhaust gas. Therefore, more considerations have been taken into the utilization of alternative fuels in engines. Depletion of fossil fuel is forcing us to find out alternative fuels. Depletion and rise in demand of these fuels increased its cost. Today the fossil fuel price controls the world economy. This will greatly affect the economic growth of developed and developing countries that has no fossil fuel sources. Fossil fuels used by these countries is mainly for the power production and the transporting purposes. Use of fossil fuels resulted in degradation of environmental health. Internal Combustion Engines are the main consumer of these fuels. Combustion of fossil fuels in the engine exhausted greenhouse gases. Greenhouse gases are the main cause behind the global warming and climate change. Both the developed countries and the developing countries are in a track to reduce the greenhouse gases. In this scenario, the investigation and use of alternate fuels source is a main concern of these countries. Research is mainly focused on find out the new fuels sources from the plants, animal waste and from human waste. Oils extracted from the plant seeds and animal waste can be directly used as energy sources but some limitations are there. Some researchers are working on biofuels and some another researcher are working on fuel blends. For each researches they need to find out better combustion, performance, and lower emission characteristics.

Modern industrial processes depend heavily on acetone as one of the extensive organic solvents. Acetone is an extensive solvent for synthetic fibers and most plastic materials such as bottles made of polystyrene, polycarbonate, polypropylene and others. Acetone is also used as a basic ingredient in paints and varnishes industries as well as many industrial applications. This multi-industrial use of acetone results, without a doubt, in large quantities of acetone containing wastes. Unfortunately, when disposing of such wastes many environmental problems appear. By burying the wastes underground, acetone can penetrate to groundwater and in turn dissolved together because acetone does not absorb to soil but it is highly soluble in water; thus contamination of groundwater occurs due to the high toxicity of acetone. On the other hand, disposing of such wastes through burning is also known to express, in some conditions, for releasing of acetone into the atmosphere. Acetone in the atmosphere is known to play an important role in changing the chemistry of the environment and it is also found to be the most oxygenated organic in the upper troposphere. In addition, acetone in the atmosphere can cause serious health problems in the central nervous system, kidneys, reproductive system, liver, skin and others. Repeated exposure to acetone may cause organ damages. Recently, the level of acetone in water and air is reported to be about 20 parts per million (ppm) and 13 to 20 ppm, respectively, and such levels should be minimized. Various techniques have been developed for acetone emission disposal. One of themost promising techniques is using catalytic combustion of acetone (after separation from other mixed components) to convert it into carbon dioxide and water. This technique mainly depends on the catalytic performance of the catalyst, which is the most important factor determining the effectiveness of this technique. Generally, two types of catalysts are commonly used: noble metal and transition metal oxides. The noble metal oxide type is very costly, which limits its broad applications. The transition metal oxide type, on the other hand, is less costly but its stability under some operating conditions is poor where its deactivation is frequently observed. In the current study a new technique is applied, which is based on the combustion of acetone in the spark-ignition (SI)
engines. Such new technique is very challenging since little is known about acetone chemical behavior in a hot oxidizing environment and therefore its practical combustion in SI engines.

II. METHODOLOGY
1. BLEND PREPARATION
   Sample 1- Gasoline
   Sample 2- Acetone 3% and Gasoline 97%.
   Sample 3- Acetone 6% and Gasoline 94%.
   Sample 4- Acetone 9% and Gasoline 91%.

   To prepare samples it is necessary to take measuring flask and a can to store it. Samples are made by percentage volume basis.
   Step 1- Take the measuring flask, measure 3% Acetone by volume.
   Step 2- Pour the measured Acetone in a can.
   Step 3- Add 97% gasoline by volume in measuring flask. Step 4- Mixing is done using magnetic stirring well. Repeat the above procedure for next sample.

2. ENGINE PERFORMANCE TEST

   Experiments to be tested by performing load test in SI engine test rig. The test rig consists of Maruti Suzuki 800cc engine with MPFI injection system. Engine consists of three cylinder and water cooled cooling system. Engine is equipped with fuel measuring tube and sensors to analyze combustion. The test rig is equipped with digital display unit which shows load acting on engine. Engine is connected with computer to analyze performance while running. Engine is coupled with hydraulic dynamometer. Load acting on engine is measured by load cell present in dynamometer.

3. EMISSION TEST
   Emission test is done using AVL dye gas analyzer.
Three copper constantan thermocouples were fitted to measure the temperatures at the inlet of the cooling water, at the outlet of the cooling water and the exhaust. These thermocouples were calibrated. A separate fuel tank was fitted for easy filling of the fuel and cleaning. The specifications of the engine are given in the table.

4. CALORIFIC VALUE

Bomb Calorimeter is used to check the calorific value of fuel samples. It consists of C200 (Calorimeter) and RC 2 (constant water temperature bath. The amount of heat released when water after combustion is condensed is called higher calorific value. The amount of water after combustion is vapour state is called lower calorific value.

5. SCHEMATIC DIAGRAM

The schematic diagram of experiment setup is shown below.

The experiments are conducted using spark-ignition engine, which has a 3-cylinder and four strokes placed on a chassis and connected with a dynamometer. The engine is air cooled with a 9:2 compression ratio and without catalytic converter unit. The displacement volume is 147.7 CC with 2 valves per cylinder. The engine was operated with the throttle plate open at speed of 1500 r/min and load range of 1–13 Kg. ECU (electronic control unit) was used in the engine setup for controlling air/fuel ratio, which is changed with engine speed/power but it is not tuned for different fuels. Engines specifications are summarized in Table 4.1. Different sensors and apparatuses are equipped with the engine to carry out the engine performance measurements as temperature sensor, pressure sensor, speed sensor etc. Different connectors are employed to feed signals from different sensors to the amplifier and then to the data acquisition card that is connected with a personal computer (PC).

<table>
<thead>
<tr>
<th>Fuel properties [34-40]</th>
<th>Acetone</th>
<th>Gasoline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular formula</td>
<td>C3H6O</td>
<td>C8H15</td>
</tr>
<tr>
<td>Octane number</td>
<td>110</td>
<td>90-99</td>
</tr>
<tr>
<td>Oxygen content (wt%)</td>
<td>27.8</td>
<td>-</td>
</tr>
<tr>
<td>Density at 15 °C (g/ml)</td>
<td>0.791</td>
<td>0.745</td>
</tr>
<tr>
<td>Autoignition temperature (°C)</td>
<td>520</td>
<td>420</td>
</tr>
<tr>
<td>Flash point at closed cup (°C)</td>
<td>178</td>
<td>-45 to -38</td>
</tr>
<tr>
<td>Lower heating value (MJ/kg)</td>
<td>29.0</td>
<td>42.7</td>
</tr>
<tr>
<td>Boiling point (°C)</td>
<td>561</td>
<td>25-215</td>
</tr>
<tr>
<td>Stoichiometric AF ratio</td>
<td>9.54</td>
<td>14.7</td>
</tr>
<tr>
<td>Latent heat at 25 °C (kJ/kg)</td>
<td>518</td>
<td>388-500</td>
</tr>
<tr>
<td>Flammability limits (vol%)</td>
<td>2.8-12.8</td>
<td>0.6-8</td>
</tr>
<tr>
<td>Saturation pressure at 38 °C (kPa)</td>
<td>53.4</td>
<td>31.01</td>
</tr>
<tr>
<td>Viscosity at 40 °C (mm²/s)</td>
<td>0.35</td>
<td>0.4-0.8</td>
</tr>
</tbody>
</table>
Table 2.2 Fuel Properties

The PC allows for data recording and displaying in various forms via the PC monitor. The experimental procedure is applied as following: (1) filling the system with fuel, (2) commissioning apparatus and sensors, (3) starting the engine using DC motor, and (4) operating the engine instead of steady state conditions. After starting up the engine, it works without load for few minutes to warm up and, afterward, measurements take place. Four different fuels are measured, which are neat gasoline (as base fuel), 3 vol.% acetone in gasoline, 6 vol.% acetone in gasoline and 9 vol.% acetone in gasoline. Properties of acetone and gasoline used in this study are presented in Table 4.2. The experiments of all fuels were applied at same engine working conditions without tuning.

III. RESULTS AND DISCUSSIONS

Results demonstrate the emissions and performance characteristics of acetone–gasoline blends as well as pure gasoline fuel at steady state working conditions; consequently, the use of acetone as a fuel in SI engine is evaluated and discussed. Combustion mechanism of acetone in SI engine is also highlighted for further understanding of engine performance and emissions. In the results, the three different blended rates of acetone–gasoline fuels are denoted as AC3, AC6 and AC9 where the “AC” designates acetone and the number next to “AC” designates the volume percentage of acetone. For example, the AC9 means that 9% acetone was blended with 91% gasoline by volume. Accordingly, the study limits the acetone content in the blends to be up to 10 vol.%; more reasons for limiting acetone content in gasoline have been demonstrated later. We found a better combustion of the air fuel mixture due to the presence of the extra oxygen in the acetone. Better combustion gave much more heat to the engine. So in order to reduce the high exhaust temperature we can use lean mixtures to the cylinder inlet. Due to the better combustion of the charge, the emissions will be reduced. And which can even result in better engine performance with improved efficiency.

The graphs from the experiments are plotted below:

1. Break Thermal Efficiency

![Fig3.1 Brake thermal efficiency vs BMEP](image)

The brake thermal efficiency of the blend is higher than that of the pure gasoline. A low BMEP range the efficiency is almost same for gasoline, A3 and A6. The increase in the thermal efficiency is due to the presence of oxygen, which leads to better combustion of the charge. This results in more power output. In other words, added acetone produce lean mixture, that increases the relative air fuel ratio to a higher value and make the burning more efficient.

2. Specific Fuel Consumption

![Fig3.2 Specific fuel consumption vs BMEP](image)
The specific fuel consumptions are almost similar for both the blend and pure gasoline. As the BMEP increases, SFC decreases. SFC for the blend is slightly greater than that of the pure gasoline. This change is due to the change in the density of the charge. The density of the charge increases with the increase in the percentage of the acetone added.

3. HC EMISSION

![Fig3.3HC Emissions vs BMEP](image)

As the percentage of acetone increases, emission of the hydrocarbon reduces. It is due to the presence of oxygen in the acetone. Presence of oxygen helps to increase the rate of combustion. It further reduces the amount of unburned hydrocarbons. Emissions are lower due to greater knock resistance of the fuel allowing higher compression ratios to be used and that knock resistance was mainly a function of the oxygen content of the blend.

4. CO EMISSION

![Fig3.4CO Emissions vs BMEP](image)

CO emission decreases with the increase of the butanol content in the mixture. It is due to the presence of oxygen in the acetone. It consists of 21.1% of oxygen. This oxygen also will take part in the combustion process. This further reduces the CO emission. The change in the CO emission is due to the leaning effect caused by lower stoichiometric air fuel ratios of the fuels due to their partially oxidized nature.

5. NO\textsubscript{X} EMISSION
Emission of NOx is higher for the blends. It is due to the increase of the combustion temperature, which is caused by the presence of oxygen in the acetone. As the amount of the acetone increases percentage of the oxygen content will be increased. This will result in the production of NOx. The higher NOx emission is due to the lower enthalpies of vaporization and higher flame temperature. Higher flame temperature is obtained due to the lower energy density of the acetone.

IV. CONCLUSION

While no evaluation of the combustion characteristics of acetone in a gasoline-fueled engine is presented in early studies, several factors are identified in this work to significantly investigate the performance and pollutant emissions of acetone–gasoline blended fuels. Experiments have been carried out with fuel blends containing 3, 6 and 9 vol.% acetone in gasoline as well as the neat gasoline fuel. Engine was operated with each blend at 1600 r/min. Based on this work, the following conclusions may be drawn:

- The use of acetone–gasoline blends leads to a boost in both fuel conversion efficiency and engine performance.
- Acetone needs a longer induction time to be decomposed, but as soon as vaporized, it speeds up the combustion once the reaction started.
- As acetone content increases in the blends, specific fuel consumption decreases.
- Three factors have been identified to significantly influence on SI engine performance and emissions at using acetone–gasoline blends: inducted charge of air, rate of acetone in the fuel blends and engine speeds.
- The SI engine set up could be maintained without any necessary modifications/adjustments when acetone content is below 10% by volume.
- Acetone is a very promising alternative fuel to be directly used in SI engines. Adding acetone is sort of activating the combustion of gasoline fuel. But engine systems must be of high quality before using acetone in the engine.

REFERENCES
