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 blendshas been studied in a gasoline-fueled engine. The blended fuels were tested for their energy efficienciesand 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 overthe neat gasoline. As the acetone content increases inthe blends, as the engine performance improved where the best performance obtained in this study atthe blended fuel of AC9. compared to neat gasoline. In addition, the use of acetone with gasoline fuel reduces exhaust emissions averagelyby about 43% for carbon monoxide, 32% for carbon dioxide and 33% for the unburnt hydrocarbons. Theenhanced engine performance and pollutant emissions are attributed to the higher oxygen content, slightleaning 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 fossils 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 toexpress, 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

Fig.2.1 Spark Ignition Engine Test Rig

MAKE	MARUTI 800CC ENGINE
NUMBER OF CYLINDERS	3
NUMBER OF STROKES	4
FUEL	PETROL
COOLING SYSTEM	WATER COOLED
POWER	27.6 KW AT 5000 RPM
TORQUE	59NM AT 2500RPM
STROKE LENGTH	72MM
BORE	66.5MM
COMPRESSION RATIO	9.2

Table 2.1- SI engine specification

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.

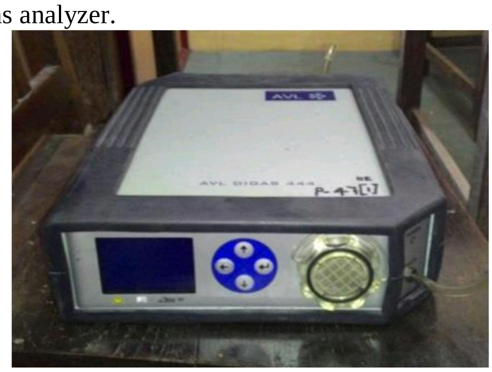


Fig.2.2 AVL Dye Gas Analyzer

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.

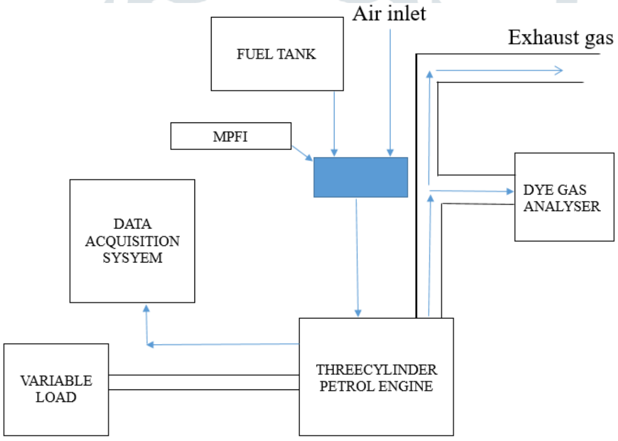
4. CALORIFIC VALUE

Fig.2.3 Bomb Calorimeter

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

Fuel properties [34–40].

Properties	Acetone	Gasoline
Molecular formula	C3H6O	C8H15
Octane number	110	90–99
Oxygen content (wt%)	27.6	–
Density at 15 C (g/mL)	0.791	0.745
Autoignition temperature (°C)	560	420
Flash point at closed cup (°C)	17.8	−45 to −38
Lower heating value (MJ/kg)	29.6	42.7
Boiling point (°C)	56.1	25–215
Stoichiometric AF ratio	9.54	14.7
Latent heat at 25 °C (kJ/kg)	518	380–500
Flammability limits (vol.%)	2.6–12.8	0.6–8
Saturation pressure at 38 °C (kPa)	53.4	31.01
Viscosity at 40 °C (mm^2/s)	0.35	0.4–0.8

Table 2.2 Fuel Properties

The PCallows for data recording and displaying in various forms via the PCmonitor. The experimental procedure is applied as following: (1) fillingthe system with fuel, (2) commissioning apparatus and sensors, (3)starting the engine using DC motor, and (4) operating the engine insteady state conditions. After starting up the engine, it works withoutload for few minutes to warm up and, afterward, measurements takeplace. Four different fuels are measured, which are neat gasoline (asbase fuel), 3 vol.% acetone in gasoline, 6 vol.% acetone in gasoline and9 vol.% acetone in gasoline. Properties of acetone and gasoline usedin this study are presented in Table 4.2. Theexperiments 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 atsteady state working conditions; consequently, the use of acetoneas a fuel in SI engine is evaluated and discussed. Combustion mechanism of acetone in SI engine is also highlighted for furtherunderstanding of engine performance and emissions. In the results,the three different blended rates of acetone–gasoline fuels aredenoted as AC3, AC6 and AC9 where the “AC” designates acetoneand the number next to “AC” designates the volume percentage ofacetone. 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 to10 vol.%; more reasons for limiting acetone content in gasoline willbe demonstrated later. We found a better combustion of the air fuel mixture due to the presence of the extraoxygen in the Acetone. Better combustion gave much more heat to the engine. So in order toreduce the high exhaust temperature we can use lean mixtures to the cylinder inlet. Due to thebetter combustion of the charge, the emissions will be reduced. And which can even result tobetter engine performance with improved efficiency.

The graphs from the experiments are plotted below:

1. Break Thermal Efficiency

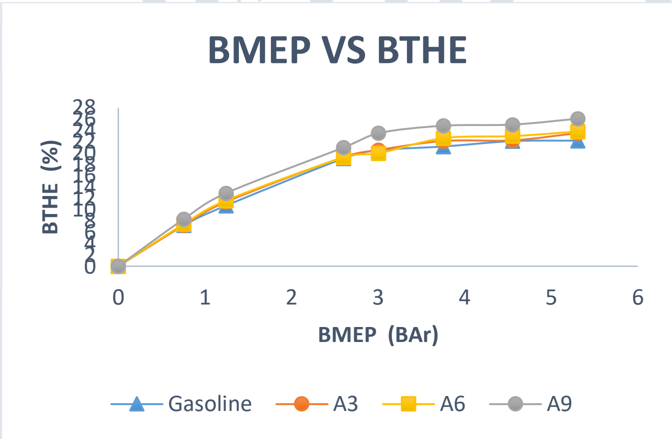


Fig3.1 Brake thermal efficiency vs BMEP

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

2. SPECIFIC FUEL CONSUMPTION

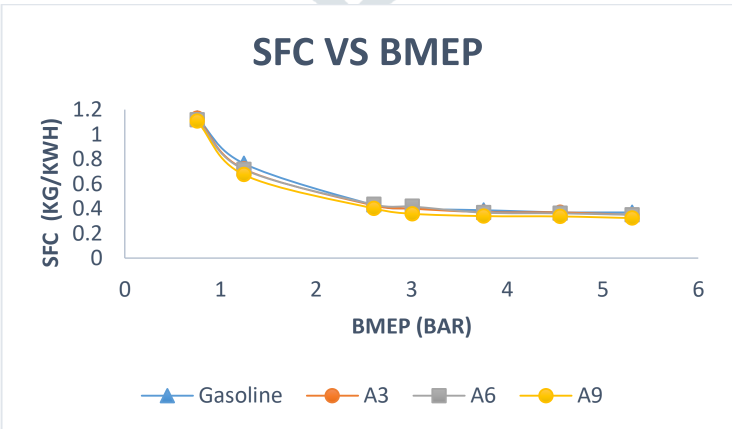


Fig3.2 Specific fuel consumption vs BMEP

The specific fuel consumptions are almost similar for both the blend and puregasoline. As the BMEP increases, SFC decreases. SFC for the blend is slightly greater thanthat of the pure gasoline. This change is due to the change in the density of the charge. Thedensity of the charge increases with the increase in the percentage of the acetone added.

3. HC EMISSION

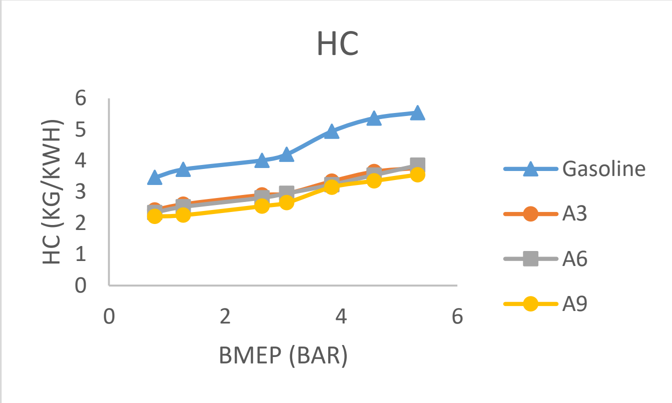


Fig3.3HC Emissions vs BMEP

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

4. CO EMISSION

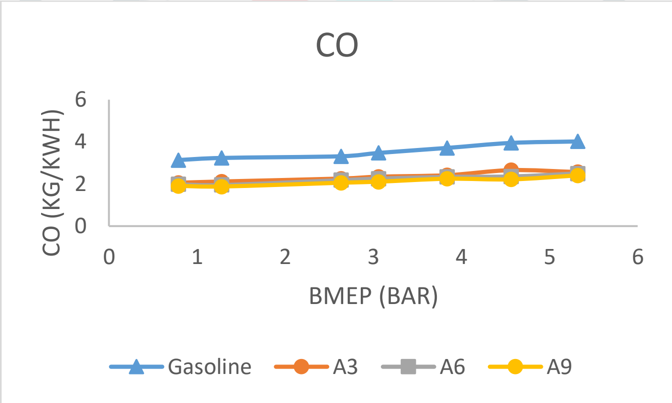


Fig3.4CO Emissions vs BMEP

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

5. NO_X EMISSION

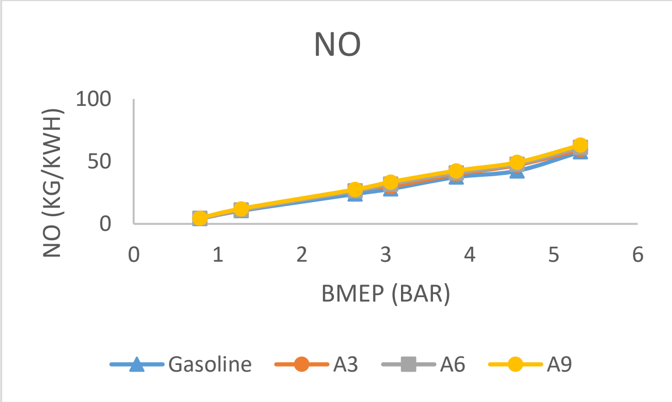


Fig3.5 NOxEmissions vs BMEP

Emission of NOx is higher for the blends. It is due to the increase of the combustiontemperature, which is caused by the presence of oxygen in the acetone. As the amount of theacetone increases percentage of the oxygen content will be increased. This will result in theproduction of NOx. The higher NOx emission is due to the lower enthalpies of vaporizationand higher flame temperature. Higher flame temperature is obtained due to the lower energydensity of the acetone.

IV. CONCLUSION

While no evaluation of the combustion characteristics of acetonein a gasoline-fueled engine is presented in early studies, severalfactors 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. Basedon this work, the following conclusions may be drawn:

- The use of acetone–gasoline blends leads to a boost in both fuelconversion efficiency and engine performance.
- Acetone needs a longer induction time to be decomposed, butas soon as vaporized, it speeds up the combustions once the reaction started.
- As acetone content increases in the blends, specific fuel consumption decreases.
- Three factors have been identified to significantly influence onSI engine performance and emissions at using acetone–gasolineblends: inducted charge of air, rate of acetone in the fuel blendsand engine speeds
- The SI engine set up could be maintained without any necessary modifications/adjustments when acetone content is below10% by volume.
- Acetone is a very promising alternative fuel to be directly usedin SI engines. Adding acetone is sort of activating the combustion of gasoline fuel. But engine systems must be of high qualitybefore using acetone in the engine.

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