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Performance Analysis of Four Stroke SI Engine Running on Flex Fuel Mixture

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Abstract: We are using the available non-renewable resources at a rate that surpasses its rate of replenishment. So we need to efficiently use the fuels available and extract maximum energy from it. Using fuel mixtures of appropriate compositions mixed by volume/ mass called the flexible fuel mixture is a step to improve the fuel efficiency and engine performance parameters. Fanhua ma et al [1] studied the performance of an engine powered by mixture of CNG and hydrogen and results show that parameters such as brake thermal efficiency, brake specific fuel consumption depend on the ratio in which these fuels are mixed. Gasoline is widely used fuel for SI engines. Nowadays gasoline is blended with ethanol and this mixture is used as fuel for engines. In this research work, the performance of a 4stroke variable speed IC engine running on different combinations of Gasoline and Ethanol at different speeds and loads is analysed and the effect of fuel mixtures on power output of engine and fuel efficiency is checked and improved.

Keywords: Flex fuel mixture, Research Octane Number, Motor Octane Number, Anti Knock Index, Reid Vapour Pressure.

I. INTRODUCTION

An Internal Combustion engine is a heat engine where the combustion of a fuel occurs with an oxidizer (usually air) in a combustion chamber that is an integral part of the working fluid flow circuit. In an internal combustion engine the expansion of the high-temperature and high-pressure gases produced by combustion of fuel apply direct force to piston. Thus transforming chemical energy of fuel into useful mechanical energy

The fuels which will be mixed for the flex fuel engine are Gasoline and Ethanol. Plain gasoline is a mixture of hydrocarbon substances of various formulas and widely-varying formula weights. Consequently, no two batches of gasoline are ever exactly alike. Although the formula varies, it is close to C_8H_{18}. Gasoline is immiscible with water in any proportion at all. It does not absorb moisture from the air, but atmospheric moisture condensation can occur on inside tank surfaces. Ethanol is a pure chemical substance with the formula C_2H_5OH (or empirically C_2H_6O), it is miscible with water in all proportions, with quite an affinity for moisture absorption, even from the air. Every batch of pure ethanol is exactly like every other batch of pure ethanol, in every way. [13]

These fuels will be mixed and the four stroke SI engine will run over the flex mixtures. The engine-fuel parameters are obtained from the experiment. The fuel mixture properties will be obtained with the help of ASTM (American Society for Testing and Materials) tests. Hopefully the tests ran well and the work and experiment done is presented here.

II. METHODOLOGY

Gasoline is widely used in current SI engines. It is a non-renewable fossil fuel, and due to its limited resources and increasing demand, gasoline is being costly day by day. After some time, all the resources of gasoline will be exhausted. So using alternative fuels is the need of the hour. Running a gasoline engine entirely on alternative fuels like ethanol needs many engine modifications. This can be avoided by using fuel mixture of gasoline and ethanol, like E10. This will help in less gasoline consumption and save this non-renewable energy resource. Ethanol is a renewable fuel and thus can be used easily and is readily available.

Another advantage of using fuel mixture is increase in engine performance. Fanhua Ma et al [1] studied the performance of an IC engine with fuel mixture of hydrogen and CNG. Many experiments were performed using different proportions of hydrogen in CNG at different engine loading conditions. Compared with natural gas, HCNG (Hydrogen enriched CNG) has many advantages when it comes to performance. Research has shown that the brake effective thermal efficiency increases with an increased percentage of hydrogen. Similarly the mixture of gasoline and ethanol improves the fuel efficiency. Ethanol also contains hydrogen, thus improving the brake effective thermal efficiency.

The ethanol and gasoline can be mixed in different proportions and have “E” numbers that denote the percentage of ethanol fuel mixed in the volume like, E10, sometimes called gasohol, is a fuel mixture of 10% anhydrous ethanol and 90% gasoline that can be used in the internal combustion engines of most modern automobiles.E15 contains 15% ethanol and 85% gasoline. This is generally the highest ratio of ethanol to gasoline that is possible to use in vehicles recommended by the U.S. Renewable Energy Laboratory.E20 contains 20% ethanol and 80% gasoline and etc.

III. CALCULATIONS

For calculating the engine performance parameters we use a 4-Stroke, single cylinder SI engine attached and loaded by a rope brake dynamometer. The fuel consumption is measured using a burette and a stopwatch. The fuels taken for experiment is Gasoline and E-15.

Table 1. Specifications of the test engine.

S. No.	Description	Data
1	Type of engine	Four stroke cycle, natural air cooled petrol engine
2	Number of cylinder	Single cylinder
3	Max Power	8.3 HP (6.26 Kw)
4	Max Speed	5500 rpm
5	Bore Diameter	59 mm
6	Stroke Diameter	59 mm
7	Cubic Capacity	161.30 cc

For the calculation of fuel efficiency, we use the ASTM Tests and, we need to calculate the parameters like,

Reid Vapour Pressure (RVP): It is a common measure of the volatility of gasoline. It is defined as the absolute vapour pressure exerted by a liquid at 100 °F (37.8 °C) as determined by the test method ASTM-D-323. The test method applies to volatile crude oil and volatile non-viscous petroleum liquids, except liquefied petroleum gases.

Research Octane Number (RON): It is determined by running the fuel in a test engine with a variable compression ratio under controlled conditions, and comparing the results with those for mixtures of iso-octane and Heptane. [8]

Motor Octane Number (MON): It is a better measure of how the fuel behaves when under load, as it is determined at 900 rpm engine speed, instead of the 600 rpm for RON.

Anti-Knock Index (AKI): It is the headline octane rating shown the pump and also known as the pump octane number. The AKI of a fuel approximates the Road octane ratings. It is sometimes also called the Posted Octane Number (PON).

ASTM D323: Sstandard Test Method for Vapour Pressure of Petroleum Products. This test method covers procedures for the determination of vapour pressure of gasoline, volatile crude oil, and other volatile petroleum products. [9]**.** Significance and uses are: Vapour pressure is an important physical property of volatile liquids. This test method is used to determine the vapour pressure at 37.8°C (100°F) of petroleum products and crude oils with initial boiling point above 0°C (32°F). Vapour pressure is critically important for automotive gasolines, affecting starting, warm-up, and tendency to vapour lock with high operating temperatures or high altitudes.

ASTM D2699: Standard Test Method for Research Octane Number of Spark-Ignition Engine Fuel [9] Its significance and uses are: Research on correlates with commercial automotive spark-ignition engine antiknock performance under mild conditions of operation. Research on is used by engine manufacturers, petroleum refiners and marketers, and in commerce as a primary specification measurement related to the matching of fuels and engines. Empirical correlations that permit calculation of automotive antiknock performance are based on the general equation:

Road O.N.=[(k_1 * Research O.N.)+(k_2 * Motor O.N.)+k_3] (1)
Values of k_1, k_2, and k_3 vary with vehicles and vehicle populations and are based on road-O.N. determinations.
Antiknock Index=[(0.5*Research O.N.)+(0.5 Motor O.N.)] (2)

Antiknock Index = [(R+M)/2] (3)

ASTM D 1298: Standard Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum by Hydrometer Method [10]. Its significance:
This test method covers the laboratory determination using a glass hydrometer in conjunction with a series of calculations, of the density, relative density, or API gravity of crude petroleum, petroleum products, or mixtures of petroleum and nonpetroleum products normally handled as liquids, and having a Reid vapour pressure of 101.325 kPa or less. Values are determined at existing temperatures and corrected to 15°C by means of a series of calculations and international standard tables. As initial hydrometer readings obtained are uncorrected hydrometer readings and not density measurements.

ASTM D86-12: Standard Test Method for Distillation of Petroleum Products at Atmospheric Pressure [11].The significance and uses of this test are: The basic test method of determining the boiling range of a petroleum product by performing a simple batch distillation has been in use as long as the petroleum industry has existed. It is one of the oldest test methods under the jurisdiction of ASTM Committee D02, dating from the time when it was still referred to as the Engler distillation.

IV. EXPERIMENTAL DATA

Table 2. Readings for Gasoline

S. No.	Weight Load (kg)	Speed (rpm)	Time taken to consume 10cc of fuel (sec)
1	4	2514	61
2	6	2392	56
3	8	2223	49
4	10	2090	40

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Table 3. Readings for E-15

S. No.	Weight Load (kg)	Speed (rpm)	Time taken to consume 10cc of fuel (seconds)
1	4	2463	64
2	6	2356	59
3	8	2210	53
4	10	2010	47

And for fuel efficiency tests, Gasoline and various mixtures of ethanol and gasoline were taken and experimented on the basis of the ASTM tests explained before. The observations are:-

Table 4. Fuel properties of pure gasoline and some ethanol-gasoline mixtures like E10, E15. [3]

Property	Test Fuels			Test Methods
	Gasoline	E10	E15	
Reid vapour Pressure	35.00	61.76	59.53	ASTM D323
Research Octane Number(RON)	84.8	86.7	88.3	ASTM D2699
Density at 15.5^0 C	0.7678	0.7730	0.7762	ASTM DI 298

Table5. Distillation temperature of pure gasoline and some ethanol gasoline mixtures like E10, E15.

	Test Fuels			Test Method
	Gasoline	E10	E15	
Initial boiling temperature ^{0}C (IBT)	38.5	39.1	39.5	ASTM D86
10 Vol%	57.2	51.5	52.3	
50 Vol%	93.5	70.2	71.8	
90 Vol%	156.0	144.5	143.7	
End Point	181.7	175.5	176.1	

V. RESULTS AND DISCUSSIONS

Brake Thermal Efficiency:-

It can be seen from the figure that the brake thermal efficiency of E15 is more than that of the Simple Gasoline fuel. As the engine load increases the brake thermal efficiency also increases

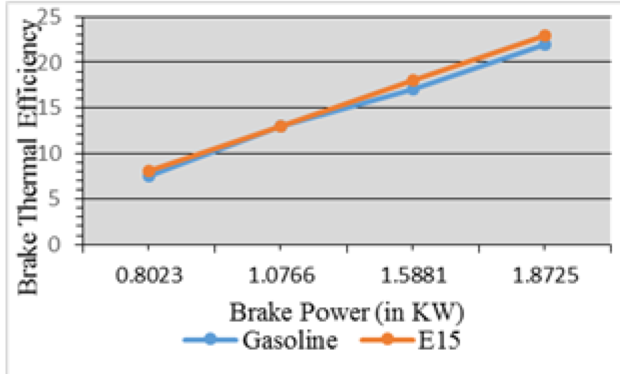

Figure 1. Brake Thermal Efficiency (in %) Vs Brake Power

Brake Specific Fuel Consumption:-

When the load increases, it can be clearly seen from the following graph that the fuel consumption of the Gasoline is more than that of E15 fuel. Hence E15 will be less consumed. So as the brake power increases the brake fuel consumption of the engine working on the E15 flex fuel mixture is less than the fuel consumed by the engine working on Pure Gasoline. So this enhances the fuel consumption efficiency as more fuel will be saved in the flexible fuel mixture engine. This makes complete use of the available fuel and there is maximum power generation.

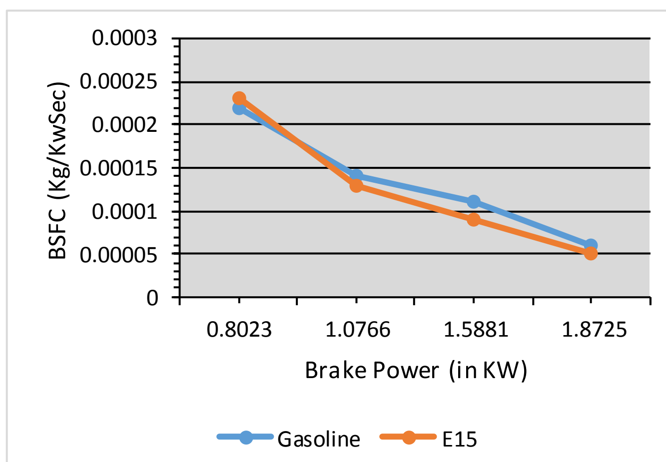

Figure 2. BSFC Vs Brake Power

Mechanical Efficiency:-

In the case of mechanical efficiency, it is observed from the graph that the mechanical efficiency of the engine running on E15 fuel is more than of the engine running on gasoline fuel. And the mechanical efficiency varies directly proportional to the composition of ethanol in the flex fuel mixture. But, the ethanol composition should not be more than 70%. Although if we are using E15 fuel mixture in the place of gasoline then we will obtain a higher mechanical efficiency and we will be able to obtain maximum power output from the engine.

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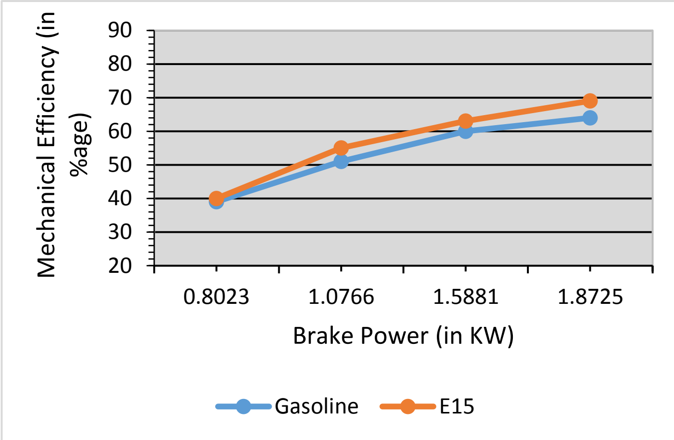

Figure 3. Mechanical Efficiency Vs Brake Power

After using the various ASTM Tests for calculating the parameters of the gasoline and ethanol fuel mixtures. Following graphs are obtained and plotted for the Effects of Ethanol blending on the Octane Number, Lower Heat Value, and Stoichiometric air-fuel ratio.

Figure 4. Show us that as we keep on increasing the volume percentage of ethanol in the flex fuel mixture of gasoline and ethanol, the motor octane number (MON), the research octane number (RON), posted octane number (PON) will increase.

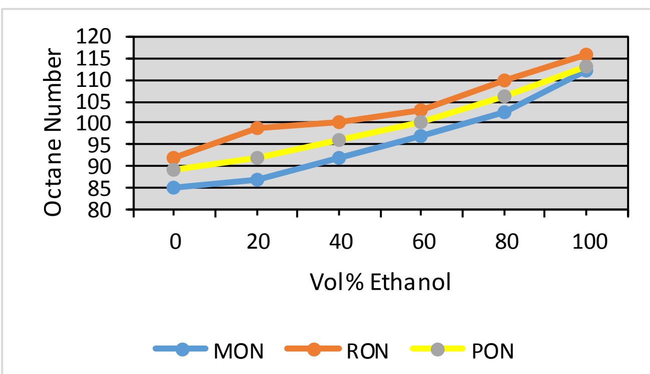

Figure 4. Effect of blend on Octane rating [13]

Figure 5. Shows the relation between the lower heat value and the fuel blend. The quantity known as lower heating value (LHV or lower calorific value (LCV)) is determined by subtracting the heat of vaporization of the water vapour from the higher heating value. This treats any H_2O formed as a vapour. The energy required to vaporize the water therefore is not released as heat. LHV calculations assume that the water component of a combustion process is in vapour state at the end of combustion, as opposed to the higher heating value (HHV). LHV assumes that the latent heat of vaporization of water in the fuel and the reaction products is not recovered. As the volume percentage of ethanol increases in the flex fuel mixture, then the value of lower heat will decrease.

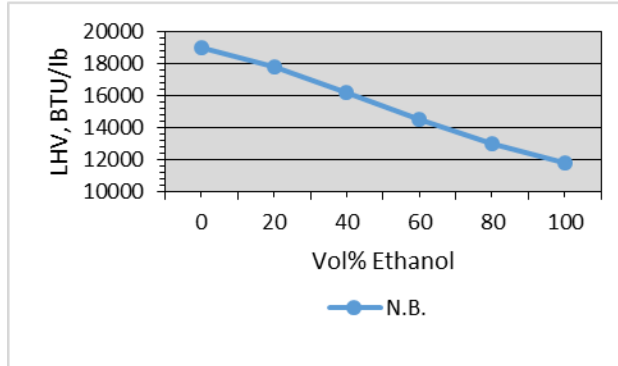

Figure 5. Effect of blend on Lower Heat Value [13]

The figure 6 shows the relation between the stoichiometric air fuel ratio by mass and the volume percentage of ethanol in fuel mixture. As the ethanol volume percentage increases the stoichiometric air fuel ratio decreases.

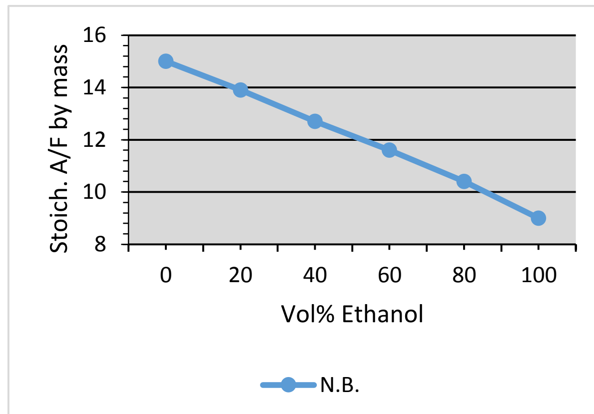

Figure 6. Effect of blend on stoichiometric Air Fuel ratio [13]

Using ethanol as a fuel additive to unleaded gasoline causes an improvement in engine performance. Ethanol addition to gasoline results in an increase in brake power, brake thermal efficiency, volumetric efficiency, and fuel consumption respectively.

CONCLUSION

In an order to make the most efficient use of the available fuels, we need to use the fuel resources in such a way that the overall fuel consumption in the engine is decreased and we obtain maximum possible output from it. From the observations and result we can say that, the concept of using fuel flexible mixtures is more efficient than the conventional single fuel systems. Thus the concept of Flex Fuel Mixtures is adequate enough to remove many drawbacks of the single fuel running engines and thus ultimately contribute to the saving of the non-renewable fuel and is good for the planet and the environment.

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