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PERFORMANCE ANALYSIS OF ETHANOL BLENDED GASOLINE FUEL IN INTERNAL COMBUSTION SPARK IGNITION ENGINE

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ABSTRACT

Growing energy needs and environmental concern worldwide have propelled the interest for quest and utilization of renewable and eco friendly fuels .Various substitutes are available to be used engines with the possibility of reducing harmful emissions. In this work gasoline is taken as reference which is blended with ethanol. Physical properties relevant to the fuel were determined for the four blends of gasoline and ethanol. A four cylinder, four stroke, varying rpm, Petrol engine connected to eddy current type dynamometer was run on blends containing 5%,10%,15%,20% ethanol and performance characteristics were evaluated. In this paper it is shown that the higher blends can replace gasoline in a SI engine, results showed that there is a reduction in exhaust gases and increase in Mechanical efficiency, Specific Fuel Consumption and air fuel ratio on blending. We can conclude from the result that using 10% ethanol blend is most effective and we can utilize it for further use in SI engines with little constraint on material used to sustain little increase in pressure.

Keywords: Spark Ignition Engine, Ethanol, mechanical efficiency, specific fuel consumption, Gasoline etc.

INTRODUCTION

1.1 Flexible fuel:-

Flexible fuel is a blend of Bio-fuel and gasoline. Generally the blend of bio fuel used in flex fuel is ethanol or methanol. Ethanol fuel is ethyl alcohol, the same type of alcohol found in alcoholic beverages. It is most often used as a motor fuel, mainly as a bio fuel additive for gasoline. The first production car running entirely on ethanol was the Fiat 147 introduced in 1978 in Brazil by Fiat. Nowadays, cars are able to run using 100% ethanol fuel or a mix of Ethanol and gasoline (aka flex-fuel). It is commonly made from biomass such as corn or sugarcane. Ethanol fuel has a "gasoline gallon equivalency" (GGE) value of 1.5 US gallons (5.7 L), which means 1.5 gallons of ethanol produces the energy of one gallon of gasoline .

The properties and others distinguished characteristics of ethanol are as follows: -

Basic Properties of ethanol :-

Formula: C_2H_5OH

Boiling point: 78.37 °C

Molar mass: 46.07 g/mol

IUPAC ID: ethanol

Density: 789 kg/m³

Melting point: -114.1 °C

Vapor pressure: 5.95 kPa

Calorific Value(CV) : 29 MJ/Kg

Table 1.1.10 Properties of fuel according the blend

Fuel	CV (MJ/L)	CV (MJ/Kg)	Octane Number
Ethanol **(E100)** i.e 100% pure ethanol	21.2	29.7	108.6
Ethanol **(E85)** I.e 85% blend of ethanol	25.2	33.2	105
Pure Gasoline/Petrol **(E0)**	34.8	44.4	91

[1]

1.2 Energy efficiency of ethanol as a fuel:-

Ethanol has 34% less energy per volume as compared to gasoline.[2] So, fuel economy with ethanol blend are significantly lower than that of gasoline. But, on the other hand this doesn't mean that the fuel economy of vehicle will directly be reduced by 34%, because There are many other variables that affect the performance of fuel in an engine.

As Ethanol has a higher octane number i.e :- 108.6 than that of gasoline i.e:- 91. Which is highly beneficial because the compression ratio of the engine is higher in the case of ethanol blended fuel.

2. HISTORY

Henry Ford's iconic Model T, built from 1908 to 1927, featured carburetor jets that could be adjusted to let the engine run on gasoline, ethanol, or a mix of the two? Yes, that capability made it the first commercially produced "flex-fuel" vehicle, though "flexing" it may have required some under-hood screwdriver fiddling.

Way back in the early 1900s, gasoline, diesel, alcohols, electricity, and other fuels were all vying for the automotive transportation market. Petroleum obviously won out and dominated without question until the 1973 oil crisis spurred an interest in increased national energy independence[3].

This opened the door to methanol and ethanol produced here at home, and between these two alcohols, ethanol emerged the winner owing to its lower toxicity, potentially greener production process, and the formidable political heft of the Iowa corn growers lobby.

In 2007, we looked at E85 flex fuel technology as a potential "fuel of the future." Now that it's 2020, let's take a hindsight look at just what flex fuel is, how it works, and what the future holds for it.

3. PERFORMANCE AND COST OF IC ENGINE WITH FLEXIBLE FUEL :-

The typical efficiency (per unit energy) of vehicles running on blends of ethanol and gasoline is similar to that of pure gasoline vehicles, although further optimization is possible. SI engines running on high blends may offer higher efficiencies (up to 9%). Potentially all future gasoline vehicles could be made compatible with all ethanol-gasoline blends from E0 to E85 (high blends require Flexible Fuel Engines) with modest cost. This is a common practice with many vehicles in the American markets (Brazil and the US). Upgrading conventional cars for use with lower percentage blends would simply cost the sum of the parts which are at risk of corrosion – approximately **3%- 6%.** The R&D costs for manufacturers to improve the compression and timing of injection for high-blend flex fuel vehicles (to optimize their efficiency) may be passed on to consumers, but it is hard to project the extent of this with certainty. Ethanol is not as volatile as gasoline or diesel, which means there may be cold starts problems in winter or in cold climates. There are several solutions to these problems, including using additives or lowering the percentage blend. The current estimated costs for bio ethanol from sugar beet, wheat, corn and sugar cane range from □ 45- □ 63 per litre of gasoline equivalent. However, costs are highly dependent on feedstock prices. Advanced biofuels from ligno-cellulosic are currently even more expensive to produce, though cost are anticipated to reduce significantly over time[4].

4. POTENTIAL AND BARRIERS OF FLEXIBLE FUEL ENGINE:-

The use of bio fuel can save significant amount of Green house Gas emission. With the extraction of ethanol from sugarcane, current biofuel from primary agricultural feedstock such as sugar beet wheat corn of a moderate CO_2 saving in compression with second generation biofuel. Moreover, bio-ethanol production from agricultural feedstock is constrained by the competition for land use with agriculture for food production. Advanced bio fuel from ligno-cellulosic material or from micro algae cold offer great savings and production capacity. These are 2nd or 3rd generation bio fuels. They have no adverse effect on land , water and soil. Presently bio fuel like E5 can be used in existing SI engine without any modifications. In south American countries like brazils E20 is also permitted in regular SI engine vehicles. Also E88 or E100 are used in flexible fuel vehicle systems (FFVs). In countries like Us, Sweden, Austria, Canada the technology of flexible fuel vehicles is already well developed. The only barrier on mass implementation of ethanol IC engines is dependency of feed stock availability[4] .

4.1 Difference between Chemical composition of ethanol and petrol

Table 4.1.1:- Comparison between properties of gasoline and ethanol

Properties	Gasoline (Petrol)	Ethanol
Chemical formula	C_8H_{15}	C_2H_5OH
Molecular weight	111.21	46.07
Oxygen content (wt%)	—	34.73
Carbon content (wt%)	86.3	52.2
Hydrogen content (wt%)	24.8	13.1
Stoichiometric AFR	14.5	8.94
Lower heating value (MJ/kg)	44.3	27
Heat of evaporation (kJ/kg)	305	840
Research octane number	96.5	111
Motor octane number	87.2	92
Vapor pressure (psi at 37.7 OC)	4.5	2
Destiny (g/cm^3)	0.737	0.785
Normal boiling point (OC)	38–204	78
Autoignition temperature (OC)	246–280	365

[5]

1. ***Formation and combustion of ethanol*** :-

i) Photosynthesis: (formation of glucose)

$6CO_2$ + $6H_20$ + light → $C_6H_{12}O_6$ + $6O_2$

264gm *108gm* *180gm* *192gm*

ii) Fermentation: (conversion into alcohol)

$C_6H_{12}O_6$ → $2C_2H_5OH$ + $2CO_2$ + heat

180gm *92gm* *88gm*

iii) Combustion of Alcohol:

$2C_2H_5O$ + $6O_2$ → $4CO_2$ + $6H_2O$ + heat

92gm *192gm* *176gm* *108gm*

In the above reaction, 1 kg of fuel gives 29.7 MJ of energy and literally no Carbon dioxide. It is because the amount of carbon dioxide used to make certain amount of glucose during photosynthesis is same as the amount of carbon dioxide released during fermentation and combustion of alcohol. In overall phenomenon this process keeps the carbon dioxide amount in the atmosphere balanced.

*2.**Combustion of octane (a major component of gasoline)** :-*

$2C_8H_{18}$ + $25O_2$ → $16CO_2$ + 18 H_2O + heat

228gm *800gm* *704gm* *324gm*

In the above reaction, 1 kg of fuel gives **44.4 MJ** energy and **1.42** kg **CO_2**. From this we can say that, the energy released during combustion of ethanol fuel is approximately 30% lower than that during the combustion of gasoline. However, the gasoline produces significantly great amount of carbon dioxide gas and releases to the open atmosphere which leads to global warming and other hazards to the environment[1].

5. PERFORMANCE OF IC ENGINE

5.1 Air fuel ratio is: The relative proportions of the fuel and air in the engine are very important from standpoint of combustion and efficiency of the engine. This is expressed either as the ratio of the mass of the fuel to that of the air or vice versa.

Air fuel ratio= **A/F** = Air flow Fuel flow …….…………………………………….. (5.1.1)

5.2 Specific fuel consumption (SFC): Brake specific fuel consumption and indicated specific fuel consumption, abbreviated BSFC and ISFC, are the fuel consumptions on the basis of Brake power and Indicated power respectively.

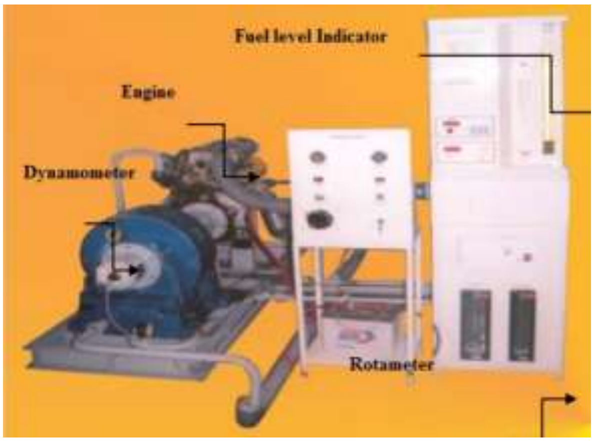
Brake specific fuel consumption (Kg/kwh): BSFC = Fuel flow in kg /hr BP ……………………(5.2.1)

5.3 Mechanical efficiency (ηm): Mechanical efficiency is the ratio of brake horse power(delivered power) to the indicated horsepower (power provided to the piston):

Mechanical efficiency: ηm = Brake Power/ Indicated Power ……………………………………(5.3.1) [6]

6. EXPERIMENTAL SET UP

The setup consists of four cylinders, four strokes, and Petrol (MPFI) engine connected to eddy current type dynamometer for loading. It is provided with necessary instruments for combustion pressure and crankangle measurements. These signals are interfaced to computer through engine indicator for Pθ−PV diagrams. Provision is also made for interfacing airflow, fuel flow, temperatures and load measurement. The set up has stand-alone panel box consisting of air box, fuel tank, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and engine indicator Rotameters are provided for cooling water and calorimeter water flow measurement. The setup enables study of engine performance for brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio and heat balance. Windows based Engine Performance Analysis software package "Enginesoft" is provided for online performance evaluation.



7. PROCEDURE

Ensure cooling water circulation for eddy current dynamometer, Piezosensor, engine cooling and calorimeter. Start the set up and run the engine at no load for 4-5 minutes. Switch on the computer and run "Enginesoft". Confirm that the Enginesoft configuration data is as given below. Gradually increase throttle to full open condition and load the engine simultaneously maintaining engine speed at @ 5000 RPM. Wait for steady state (for @ 3 minutes) and log the data in the "Enginesoft". Gradually increase the load to decrease the speed in steps of @500 RPM up to@ 2000 rpm maximum and repeat the data logging for each observation. Note the reading of Exhaust Gas using Exhaust Gas Analyzer at exhaust. View the results and performance plots in "Enginesoft".

7.1 Enginesoft Configuration data:

7.1.1 Engine and set up details

Engine power	47.7KW
Engine max speed	6200 RPM
Cylinder bore	68.5mm
Stroke length	72mm
Connecting rod length	112.5mm
Compression ratio	9.2:1
Stroke type	Four
No. of cylinders	Dour
Speed type	Variable
Cooling type	Water
Dynamometer type	Eddy current

Indicator used type	Cylinder pressure
Interface type used	PCI-1050
Calorimeter	Pipe in pipe

7.1.2 Theoretical constants:

Fuel density	740 kg/m3
Calorific value	44000 kJ/kg
Orifice coefficient of discharge	0.60
Sp heat of exhaust gas	1.00 kJ/kg-K
Max sp heat of exhaust gas	1.25 kJ/kg-K
Min sp heat of exhaust gas	1.00 kJ/kg-K
Specific heat of water	4.186 kJ/kg-K
Water density	1000 kg/m3
Ambient temperature	300^{o} C

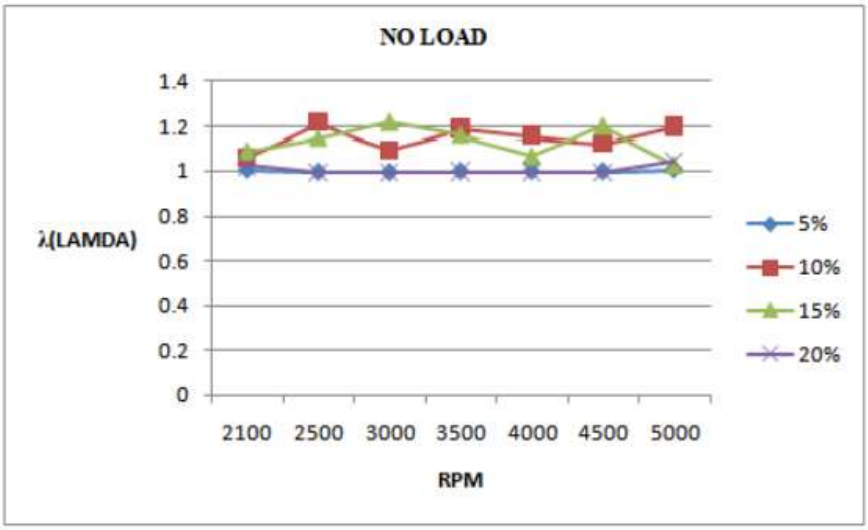
7.1.3 Sensor range

Exhaust gas temp. trans. (Engine)	0-1200 C
Air flow transmitter	-200-0 mm WC
Fuel flow DP transmitter	0-500 mm WC
Load cell	0-50 kg
Cylinder pressure transduce	0-345.5 bar

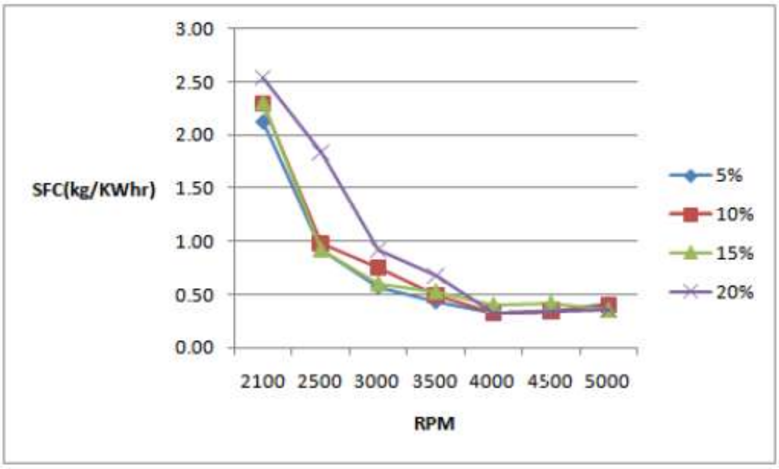
8. RESULTS AND DISCUSSIONS:-

1 No Load Test

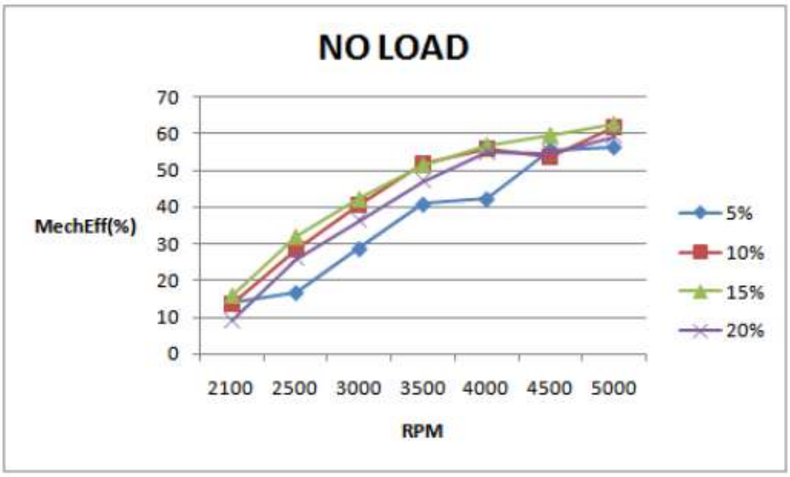
- Lambda increases from 1 to 1.2 as blending increased up to 15%. It increases by 22% at 2500 rpm for 10% blend in comparison to commercial Gasoline as shown fig 8.1.1
- Specific Fuel Consumption increases on blending Gasoline. In comparison to commercial Gasoline, it increases by 7.2% for 10% blend, 8.0% for 15%blend and 18.77% for 20%blend at 2100 rpm as shown in fig 8.1.2
- Mechanical Efficiency increases on blending Gasoline. In comparison to commercial Gasoline, it increases by 9% for 10% blend, 8.8% for 15%blend and 4.85% for 20%blend at 5000 rpm as shown in fig 8.1.3



Fig(8.1.1) Lambda variation with blends at different rpm.



Fig(8.1.2) Specific fuel consumption variation with blends at different rpm



Fig(8.1.3) Mechanical efficiency variation with blends at different rpm

2. CONSTANT RPM TEST

- Lambda decreases on blending at high loads and generally lies between 0.992 to 0.996 for 3000 rpm and 4000 rpm as shown in fig 8.2.1 and 8.2.2.

- Mechanical Efficiency increases with blending and is slightly greater at 4000 rpm. At 20kg load, it increases by 11.85% for 10%blend, 5.5% for 15% blend, 10.99% for 20% blend at 3000 rpm and increase by 3.36% for 10% blend, 2.89% for 15% blend and 1.03%for 20% blend at 4000 rpm with respect to commercial Gasoline as shown in fig 8.2.3 and 8.2.4.
- Specific Fuel Consumption increases on blending and is generally lower for 4000 rpm. At 20kg load, it increases by 5.66% for 10%blend, 14.55% for 15% blend, 40.16% for 20% blend at 3000 rpm and increase by 0.75% for 10% blend, 2.47% for 15% blend and 20.47 % for 20% blend at 4000 rpm with respect to commercial Gasoline as shown in fig 8.2.5 and 8.2.6

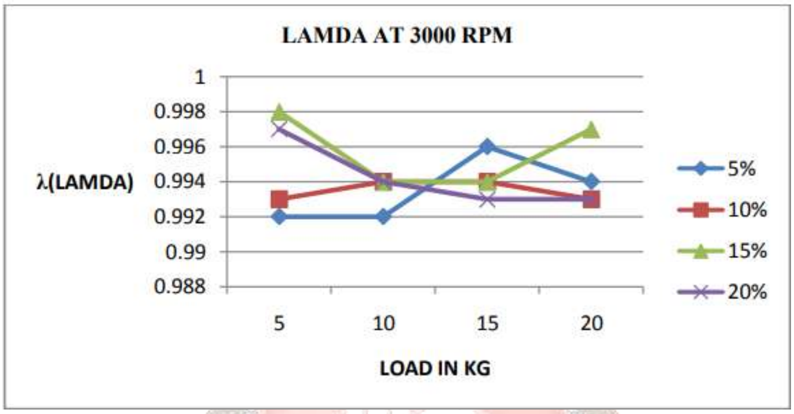
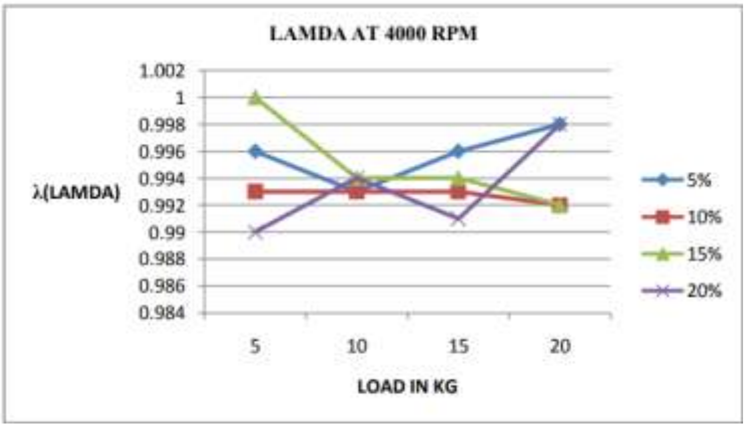
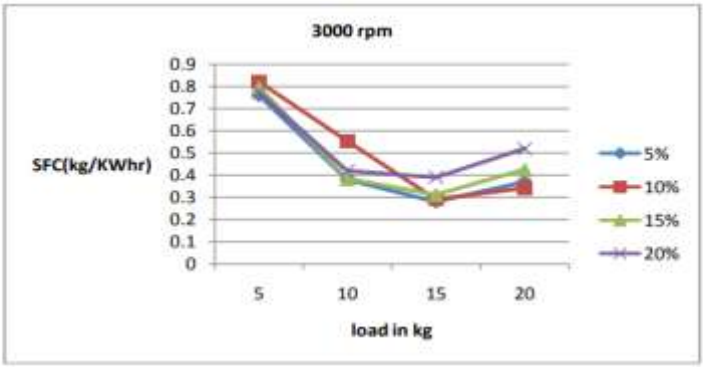


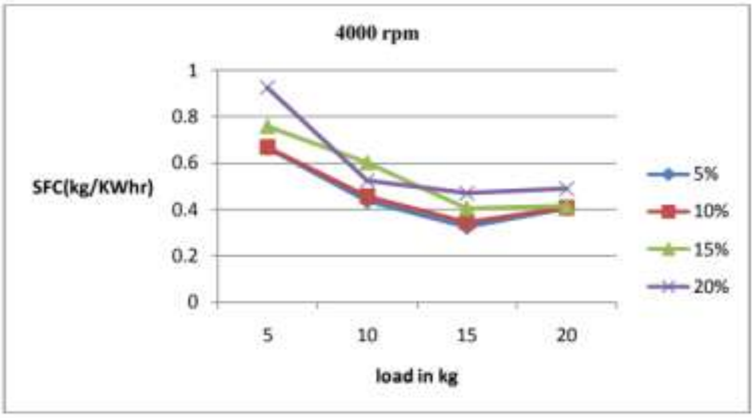
fig (8.2.1) Variation of lamda emission with load at 3000 rpm



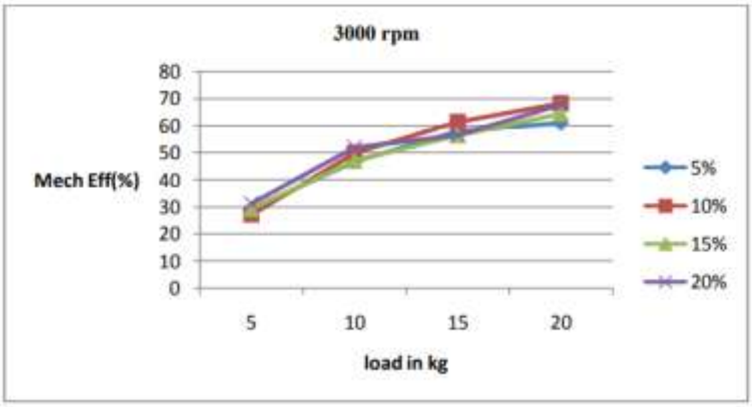
Fig(8.2.2) Variation of lambda emission with load at 4000 rpm



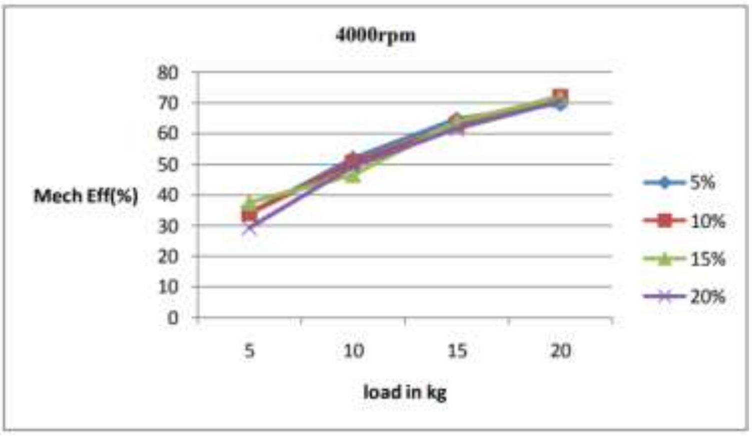
Fig(8.2.3) Variation of specific fuel consumption with load at 3000 rpm



Fig(8.2.4) Variation of specific fuel consumption with load at 4000 rpm



Fig(8.2.5) Variation of mechanical efficiency with load at 3000 rpm



Fig(8.2.6) Variation of mechanical Efficiency with load at 4000 rpm

9. CONCLUSION

From the results, it can be concluded that Ethanol blends are quite successful in replacing pure Gasoline in Spark Ignition Engine. Results clearly show that there is an increase in Specific Fuel Consumption because of low calorific Value of Ethanol than Gasoline and also increase in the mechanical efficiency. So from the curves it is seen that 10% ethanol blended Gasoline is the best choice for use in the existing Spark Ignition Engines without any modification to increase Efficiency. A little consideration has to be taken on material used as maximum pressure inside cylinder is increased by blending. A balance has to be made between Specific Fuel

Consumption and efficiency to take care of users using blend as more fuel will be consumed due to blending of ethanol with gasoline.

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