© Applied Science Innovations Pvt. Ltd., India Carbon – Sci. Tech. 8/3(2016)36-45

Carbon – Science and Technology

ISSN 0974 – 0546

http://www.applied-science-innovations.com

RESEARCH ARTICLE Received:10/03/2016, Accepted:15/04/2016

Experimental investigation of a single cylinder S.I engine fuelled with gasoline-butanol blends

Naveen Gaur, Darpan Dahiya, and Rohit Singh Lather

Department of Mechanical Engineering The NORTHCAP University, Gurgaon, India.

Abstract: Over the past decade, there is an increasing interest in alcohol based fuels around the world due to the ease of handling, blending and the potential of production using renewable resources. Butanol is one of the suitable alternative candidate for IC engines due to its lower heating value (32 MJ/kg) in comparison to other alcohol based fuels such as ethanol (26.8 MJ/kg) and methanol (20 MJ/kg). The present study was carried out to evaluate the performance and emission characteristics of a single cylinder carbureted engine fuelled with the following gasoline-butanol blends ranging from 5%, 10%, 15% and 20% of butanol by volume. During the tests negligible reduction in the performance characteristics were observed for gasoline-butanol blends in comparison to conventional gasoline. The emission characteristics of gasoline-butanol blends were observed to be superior to that of conventional gasoline. In the overall picture, the performance of gasoline-butanol blends indicated promising results as a substitute to conventional gasoline.

Keywords: S.I. Engine, butanol, emissions, performance, gasoline

---

1 Introduction: Motor cycles and scooters using carbureted spark ignition engine, sum up to a large number worldwide. Small carbureted spark ignition engines also find application in lawn movers and generator sets. Carburetor works on the principle of vaporization of liquid gasoline fuel adiabatically before its introduction into the engine cylinder. This vaporization is achieved by allowing atmospheric air, induced by engine suction, to pass through the fuel **[1]**. The overall performance in spark ignition engines is strongly affected by the type of fuel as well as the fuel induction technique **[2]**. In the past few decades there have been many evolutionary leaps towards operating internal combustion engines using non-conventional fuels. The commonly used fuel in the spark ignited engines is petroleum based gasoline. Butanol can be easily blended with conventional gasoline and can be used to run a spark ignition internal combustion engine; without any hardware modifications. Table I compares the different fuel properties of gasoline, butanol and ethanol. Butanol as a fuel has good physiochemical properties which makes it suitable for blending with gasoline, leading to improvement in combustion and emissions characteristics of the blended fuel. In a study, on single cylinder engine fuelled with iso-butanol **[3]**, a decrease in fuel conversion efficiency up to 9 % at full load and 11 % at partial load were recorded. Though blended fuel may lead to a slight drop in the efficiency of the engine, it seems to have little impact on the performance. In some investigations **[3**-5], the gasoline butanol blends when compared to pure gasoline exhibited no significant change in the performance of the engines. No modifications were done to the engine parts.

TABLE I: GASOLINE VS BUTANOL [7]

Parameters	Gasoline	Butanol	Ethanol
Chemical formula	~$C_8H_{15.6}$	$C_4H_{10}O$	C_2H_6O
Low heating value (MJ/kg)	43.5	32	26.8
Latent heat of vaporization (kJ/L)	223	474	725.4
Density (kg/m^3)	720-775	813	794
Oxygen (% weight)	<2.7	21.6	34.7
Adiabatic flame temperature (K)	2370	2340	2310
Flash Point (K)	230	302	286
RON	95	113	111
Oxygen (% weight)	<2	21.6	34.7
A/F Stoichiometric	14.6	11	9
Auto-ignition temperature (K)	553	587-670	641

In a study [6], experiments were conducted in a single-cylinder port-fuel injection SI engine. CO_2 emissions were observed to increase slightly when butanol was blended with the gasoline. A decrease in the NO emissions, along with that of unburnt HC, was noted. There was no distinguished trend observed in the CO emissions.

2 Materials and methods:

2.1 Engine: Single Cylinder Variable Compression Research Engine

The setup used in the experiments constituted of a single cylinder four stroke variable compression ratio multi-fuel research engine. Specifications of the engine are given in Table II. The engine was coupled to an eddy current dynamometer for loading.

TABLE II: ENGINE SPECIFICATIONS

Parameters	Specifications *Measurements/Description*
Engine type	Four stroke, water cooled, diesel, single cylinder, constant engine speed
Bore(mm)	87.5
Stroke(mm)	110
Compression ratio	17.5:1
Injection timing(CA)	23° BTDC
Capacity(cc)	661
Software	“Enginesoft” engine performance analysis software

Figure 1: Variable compression research engine.

The setup was well equipped with necessary instruments for the experiments to be conducted. It consisted of an air box, fuel tanks, numbering in two, for the sake of multi fuel test, a manometer, a unit for measuring fuel, air transmitters and fuel flow measuring instruments. Also in the panel a process indicator was provided with the facilitation of hardware interface. The following parameters were measured air-flow, fuel flow, exhaust gas temperatures and brake power. An engine performance acquisition and analysis software package "Enginesoft" was used for performance acquisition. Eddy current (EC) dynamometer, as shown in Figure 1, was used for loading the engine during the engine testing. Load measurement by the dynamometer was done using a strain gauge load cell and speed measurement was done by using a rotary encoder that was shaft mounted. The tests were conducted at constant speed of 1500 rpm and the loads were varied from no load condition to 20 %, 40 %, 60 % and 80 % load. A detailed text matrix is given in table III.

TABLE III: TEST MATRIX

Fuel	**Speed**	**Load%**	**Engine Parameters**	**Emission**
Gasoline	1500	0	BSEC	CO_2
BT5	1500	20	Mechanical Efficiency	HC
BT10	1500	40	Brake Thermal Efficiency	NO_x
BT15	1500	60	Torque	CO
BT20	1500	80		O_2

2.2 Emission Measurements: A gas analyser was used to analyse the exhaust emissions and to measure the different species of exhaust gases. The measurements were carried out using an AVL di-gas analyser, having the features to measure the five residual gases and air-fuel ratio. These gases included the unburned hydrocarbons (HC), Carbon dioxide (CO_2), Oxygen (O_2), Carbon Monoxide (CO) and Nitric Oxide (NO). To measure the emissions, probe of di-gas analyser was placed into the engine exhaust pipeline. The sensors identified different gases and represented the values in terms of percentage or in terms of ppm (part per million).

2.3 Types of Blends: Four blends of gasoline and butanol blends were made for carrying out the investigation. The percentage of butanol in gasoline by volume was 5 %, 10 %, 15 % and 20 % for BT5, BT10, BT15 and BT20 respectively. The modified heating values (in MJ/Kg) for each test fuel are indicated in Table IV.

TABLE IV: FUEL HEATING VALUES

Fuel	Heating Value (MJ/Kg)
Gasoline	43.5
BT5	42.98
BT10	42.46
BT15	41.94
BT20	41.42

3 Results and discussions: The following section shows the effect of blending Butanol with gasoline in proportions varying from 5% to 20% on the performance parameters such as engine torque, brake specific fuel consumption, brake specific energy consumption, thermal efficiency and mechanical efficiency with respect to engine load percent. The emission characteristics of the engine are based on the gases namely HC, CO, CO_2, NO and O_2.

3.1 Engine torque: The Figure 2 represents the variation of torque with the load for gasoline and gasoline – butanol blends. With increase in load on the engine the torque was observed to increase proportionally for all the test fuels. No torque drop was observed for gasoline – butanol blends in comparison to gasoline. Though, it has been observed that addition of alcohol in gasoline decreases its heating value, negligible change in torque can be explained by the higher oxygen content in butanol **[5]**. This signifies that butanol blends with gasoline in small proportions yield parallel torque output. This helps in achieving complete combustion, thereby leading to higher torque at lower heating values **[6]**. The results explicitly indicate that we get equal torque for gasoline and butanol blends.

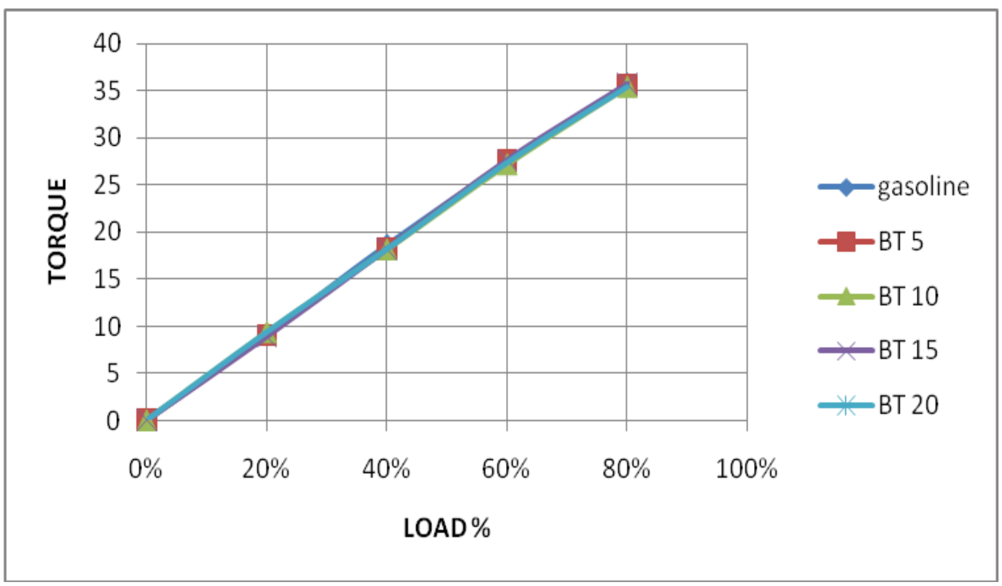

Figure 2: Variation of torque with respect to load.

3.2 Brake specific energy consumption: The Figure 3 represents the graph plotted for brake specific energy consumption against the different loads for gasoline and gasoline – butanol blends. BSEC (break specific energy consumption) is high at low loads for all the test fuels, and as we increase the load the BSEC starts decreasing. This trend follows approximately up to 50 % load and if we further increase the load then the value of BSEC starts increasing. Here we can see that the value of BSEC at higher load or even moderate load is declining but still very close in case of gasoline and gasoline – butanol blends. This decline in the BSEC is a result of decline in LHV (Lower Heating Value), when butanol is added to gasoline [8]. These trends, in the graph, clearly indicate that use of gasoline-butanol blends will yield approximately the same BSEC as does gasoline, at higher loads [9].

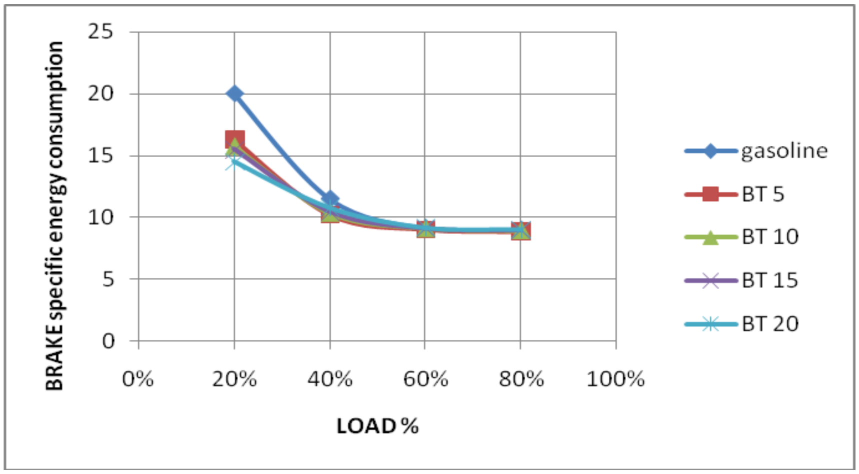

Figure 3: Brake specific energy consumption variation with load

3.3 Brake thermal efficiency: Here, Figure 4 represents the variation of brake thermal efficiency and load for gasoline and gasoline – butanol blends. As we increase the load, BTE starts increasing for every given fuel. The graph clearly indicates that, gasoline and BT 20 are at the extremes. Whereas, BT 5, BT 10 and BT 15 safely fall between the two extremes and are at par, in delivering the desired BTE, with gasoline. It appears that higher latent heat of vaporization of butanol is largely responsible for inhibiting the process of it being mixed with air, which leads to inferior combustion and thus lower BTE [10 - 11]. Since, the variations in BTE of gasoline and the given gasoline – butanol blends are comparable; it is thus, an encouraging factor towards the use of gasoline-butanol blends.

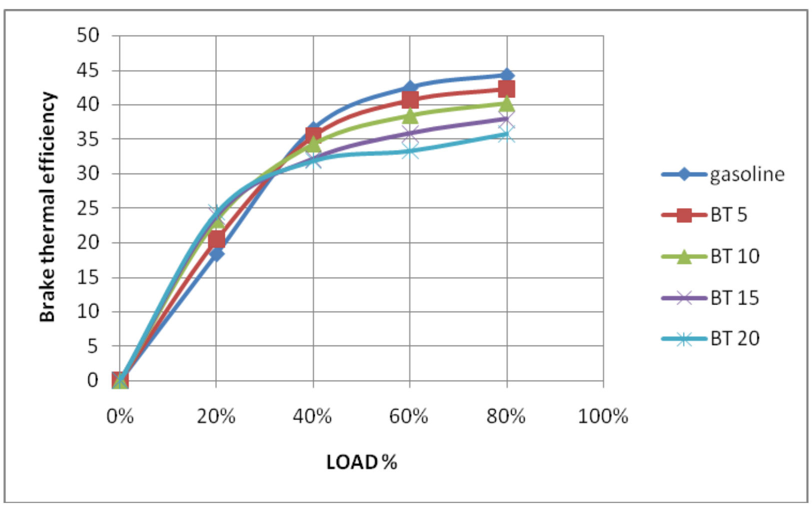

Figure 4: Variation of BTE with load

3.4 Mechanical efficiency: The Figure 5 represents the variation of mechanical efficiency with respect to change in load percentage. As in the case of BTE, the mechanical efficiency of the given fuels also shows a rapid increase with increase in the load. It can be easily comprehended from the figure that, gasoline, BT 10 and BT 20 show a steeper increase in comparison to other test fuels. At higher load percentage all the given fuels tend to deliver the same mechanical efficiency [12]. Surprisingly, BT15 and BT 20 tend to give a slight higher mechanical efficiency at higher loads, i.e. between 50% to 80% load. These findings make the gasoline-blends create confidence, in butanol as an alternative fuel.

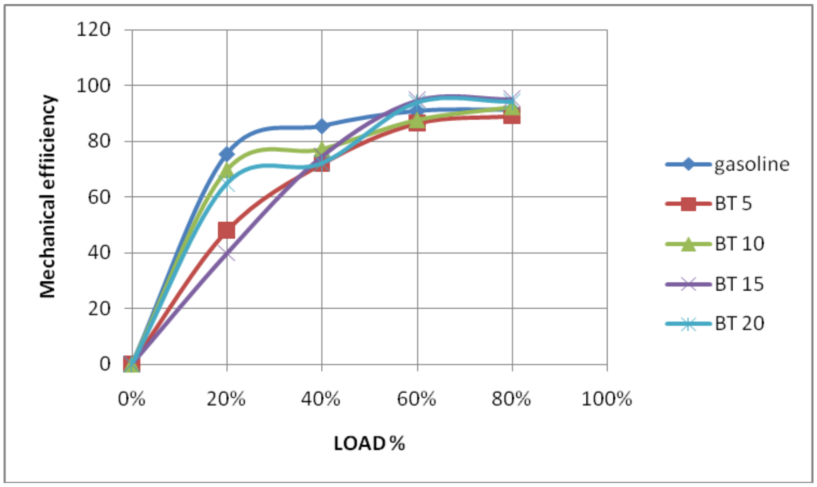

Figure 5: Variation of mechanical efficiency with respect to load.

3.5 Carbon monoxide: The Figure 6 represents the variation of CO emissions with respect to load. As we increase the load, the percentage of CO emissions increases. Whereas, when we increase the concentration of butanol in gasoline, there is a relative reduction in the CO emissions. At a no load condition when we move from pure gasoline to BT 5 (5 % butanol), there is a reduction of 2.2 % in the CO emissions. And when we use BT 20 (20 % butanol), there is a reduction of 11.34 %. When we go for observations at 80 % load, the variations for BT5 and BT 20 are 3.4 % and 18.7 % respectively. The reduction of CO on increasing the butanol concentration can be attributed to the higher oxygen content in butanol. The higher oxygen aids in the complete combustion of the test fuel **[5 - 6]**. Thus it can be assumed safely that the addition of butanol improves the combustion properties of the fuel and also increases the heat release rate.

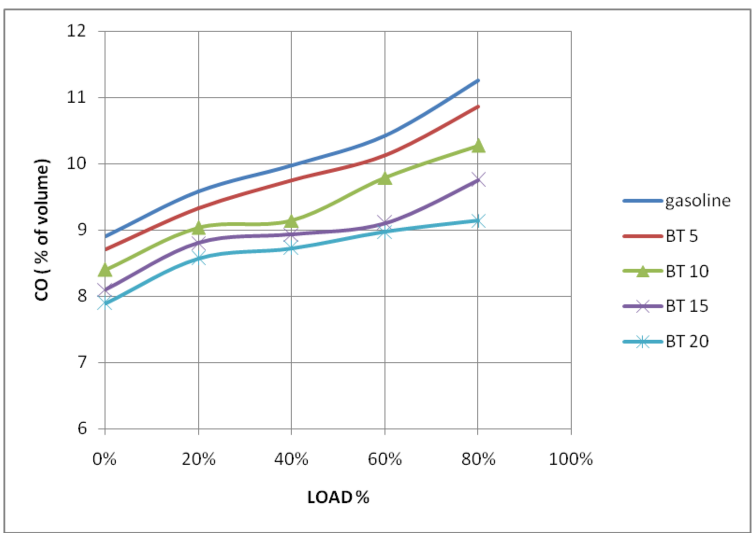

Figure 6: Variation of CO emission with respect to load.

3.6 Unburned hydrocarbons: The Figure 7 represents the emission of unburned hydrocarbons with respect load. As we increase the load the amount of unburned hydrocarbon emission reduces. And as we move from pure gasoline to BT 20 there is sharp reduction in the amount of HC emission.

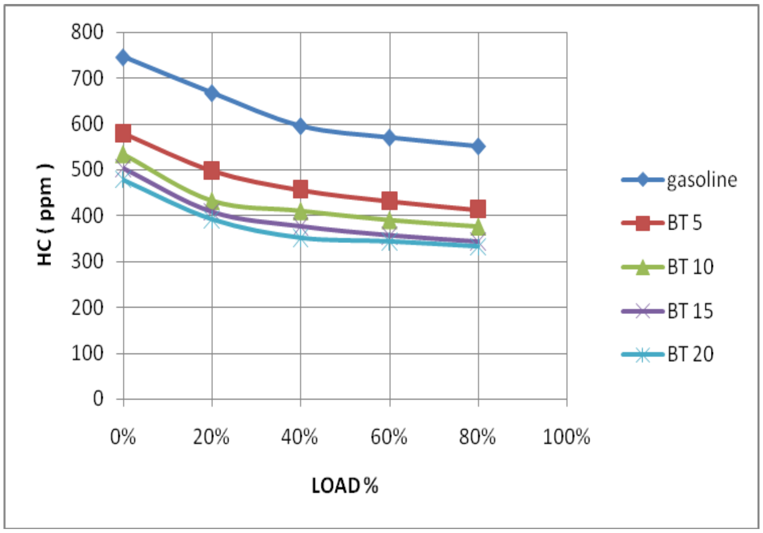

Figure 7: Variation of HC emission with respect to load.

At no load condition, there is a reduction of 22.38 % in HC emissions when we shift from pure gasoline to BT 5 and reduction of 36.16 % for BT 20. At peak load the reduction is about 25.34 % and 39.29 % respectively for BT 5 and BT 20. The emission of unburned hydrocarbon is majorly dependent on the engine design. Whereas, in this case, the higher oxygen content and the richer combustible mixture of butanol and gasoline (at higher loads), results in the improvement of the combustion properties of fuel **[6]**. The HC are one of the major pollutants. Thus reduction of HC by addition of butanol is a very welcome outcome.

3.7 NO emissions: Figure 9 represents the trends of emission of NO with respect to load. As we increase the load the NO emission reduces for all types of fuel.

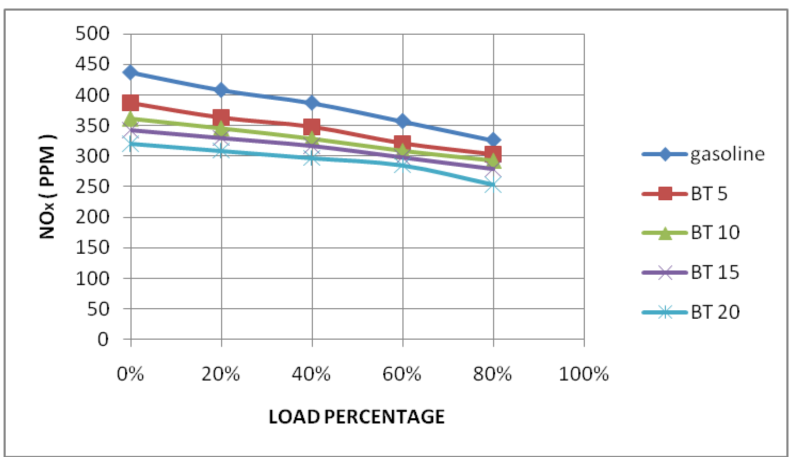

Figure 8: NO_x emission variation with respect to load.

A sharp decline in the NO emission can be seen as we shift from pure gasoline to blended fuel. At no load condition the variation in NO emission with respect to gasoline is 11.23 % and 25.49 % respectively for BT 5 and BT 20. And at peak load the variation is 7.23% and 22.39% respectively for BT 5 and BT 20. Higher oxygen concentration, temperatures during combustion and timing are the main parameters affecting the NO emissions **[13]**.

3.8 Oxygen (O_2): Figure 9 represents the reduction of O_2 as we increase the load and shift from pure gasoline to blended fuel. The reduction in O_2 implies the complete combustion and rich mixture burn.

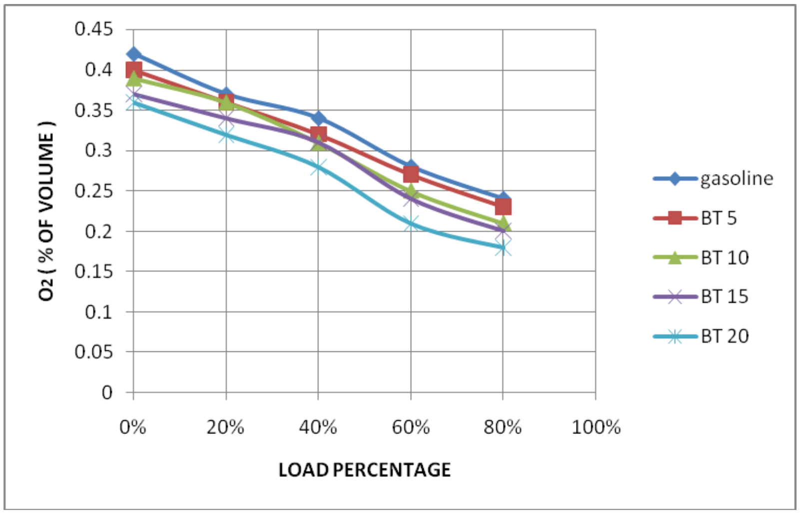

Figure 9: O_2 emissions variation with respect to load.

At peak load the variation of O_2 emission for BT 5 and BT 20 are 14.28 % and 25 % respectively. Since higher oxygen content is attributed to lower LHV, the reduction in O_2 emissions is welcomed **[5 - 6]**, as it signifies better combustion and indicates higher LHV of the test fuels.

3.9 Carbon dioxide (CO_2): The Figure 10 represents the variation of emission of CO_2 with respect to load. The percentage of CO_2 in total emission decreased when the load was increased; this is mainly due to incomplete combustion. When butanol is blended with gasoline there is an increase in the percentage of the amount of CO_2 in exhaust gases. At no load condition the change in the amount of CO_2 for BT 20 is around 1.5 %. And at peak load the variation in CO_2 is about 5.4 %. The increase of CO_2 is welcome because it signifies complete combustion **[14]**. Hence blending with butanol is a good option to reduce the demand of gasoline.

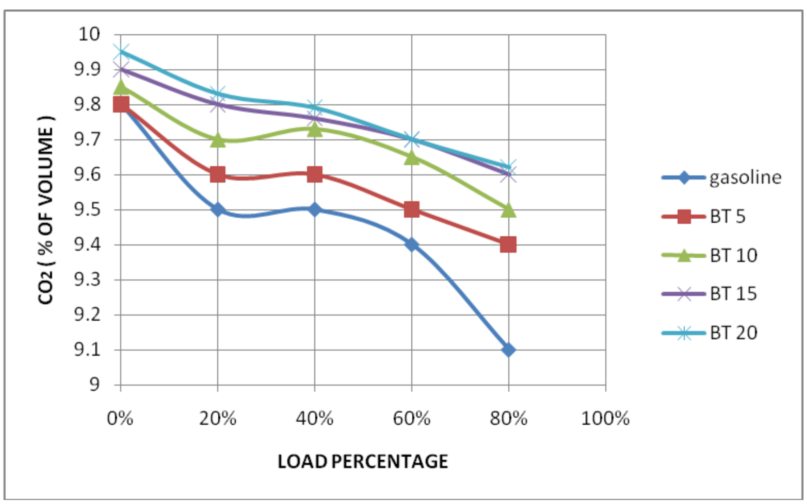

Figure 10: CO_2 emission variation with respect to load.

4 Conclusions: After completion of the experimental investigation and thorough analysis of obtained results, the following conclusions were drawn:-

1. The butanol-gasoline blend is a potential option as a alternative fuel for spark ignition internal combustion engine.
2. The performance characteristics clearly indicate that the use of butanol blend with gasoline does not affect mechanical efficiency, BSEC, brake thermal efficiency and torque considerably.
3. The emission results at peak load for BT 20 signify the reduction of about 18.7 %, 39.29 %, 22.29 %, and 25 % for exhaust gas species CO, HC, NO and O_2, respectively. There is about 5.4 % increase in the CO_2 emission at peak load for BT 20, which indicates the complete combustion.

It can be further suggested that gasoline-butanol blends up to 20 % by volume have the potential to replace the conventional gasoline.

Acknowledgement: The authors would like to acknowledge The NORTHCAP University, Gurgaon for providing a platform to carry out the present study. We are also thankful to Mr. Ravinder Kumar, lab technician, for his most required assistance in conducting the experiments.

References:

[1] M. Abu-Qudais, K. Asfar and R. Al-Azzam, 'Engine performance using vaporizing carburetor', *Energy Conversion and Management*, 42/6 (2001) 755-761.

[2] A. Irimescu, 'Fuel conversion efficiency of a port injection engine fueled with gasoline–isobutanol blends', *Energy* 36/5 (2011) 3030-3035.

[3] M. Canakci, A. Ozsezen, E. Alptekin and M. Eyidogan, 'Impact of alcohol–gasoline fuel blends on the exhaust emission of an SI engine', *Renewable Energy* 52 (2013) 111-117.

[4] A. Irimescu, 'Performance and fuel conversion efficiency of a spark ignition engine fueled with iso-butanol', *Applied Energy* 96 (2012) 477-483.

[5] J. Campos-Fernández, J. Arnal, J. Gómez and M. Dorado, 'A comparison of performance of higher alcohols/diesel fuel blends in a diesel engine', *Applied Energy* 95 (2012) 267-275.

[6] G. Broustail, F. Halter, P. Seers, G. Moréac and C. Mounaim-Rousselle, 'Comparison of regulated and non-regulated pollutants with iso-octane/butanol and iso-octane/ethanol blends in a port-fuel injection Spark-Ignition engine', *Fuel* 94 (2012) 251-261.

[7] J. Dernotte, C. Mounaim-Rousselle, F. Halter and P. Seers, 'Evaluation of Butanol–Gasoline Blends in a Port Fuel-injection, Spark-Ignition Engine', *Oil Gas Sci. Technol. – Rev. IFP* 65/2 (2009) 345-351.

[8] M. Koç, Y. Sekmen, T. Topgül and H. Yücesu, 'The effects of ethanol–unleaded gasoline blends on engine performance and exhaust emissions in a spark-ignition engine', *Renewable Energy* 34/10 (2009) 2101-2106.

[9] S. Kamboj and M. Karimi, 'A comparison of the performance analysis of the spark ignition engine fuelled with ethanol–iso-octane and methanol–iso-octane fuel blends', *International Journal of Sustainable Energy* 35/3 (2014) 205-216.

[10] S. Szwaja and J. Naber, 'Combustion of n-butanol in a spark-ignition IC engine', *Fuel* 89/7 (2010) 1573-1582.

[11] P. Veloo, Y. Wang, F. Egolfopoulos and C. Westbrook, 'A comparative experimental and computational study of methanol, ethanol, and n-butanol flames', *Combustion and Flame* 157/10 (2010) 1989-2004.

[12] R. Zhu, M. Shi, Y. Wang and J. Tan, 'Performance Comparisons of Spark-Ignition Engine Fueled with Butanol/Gasoline and Ethanol/Gasoline Blends', *AMM* 730 (2015) 275-278.

[13] F. Alasfour, 'NO_x emission from a spark ignition engine using 30% iso-butanol – gasoline blend Part 2—Ignition Timing', *Applied Thermal Engineering* 18/8 (1998) 609-618.

[14] C. Sayin, 'The impact of varying spark timing at different octane numbers on the performance and emission characteristics in a gasoline engine', *Fuel* 97 (2012) 856-861.

*****