Evaluation of Engine Performance Using Net Diesel Fuel and Biofuel Blends

Ghobadian, B.[1], Rahimi, H.[2] and Khatamifar, M[2].

Tarbiat Modares University, Tehran , Iran.Phone: 0098 21-44196522-3
bghobadian2004@yahoo.com

Abstract

Biofuels are the main substitute to fossil fuels. These fuels are less polluting in comparison to fossil fuels and can be produced from agricultural material residues. Considering the laboratory condition and fuel stability limits to be used, the suitable blending proportion of ethanol and diesel fuel was determined to be 12 to 88. For maintaining the fuel stability at temperature lower than 15^{o}C, the sunflower methyl ester was added to the mixture. The engine performance at full load and no load conditions using base diesel fuel and fuel blend including net diesel, ethanol and sunflower methyl ester blend was investigated considering fuel consumption, power and torque. The maximum power and torque produced using diesel fuel was 17.3 kW and 67.7 Nm at 3600 and 2800 rpm respectively. Adding 3% ethanol and 2% sunflower methyl ester, reduced maximum power and torque by 2.3 and 2.6% respectively and increased an average 2.2% bsfc for various speed range. Adding 6% ethanol and 4% sunflower methyl ester, reduced maximum power and torque by 4.5 and 5.1% respectively and increased an average 5.5% bsfc for various speed range. Adding 9% ethanol and 6% sunflower methyl ester, reduced maximum power and torque by 6.4 and 3.8% respectively and increased an average 8.3% bsfc for various speed range. Adding 12% ethanol and 8% sunflower methyl ester, reduced maximum power and torque by 8.1 and 6.5% respectively and increased the average 12.1% bsfc for various speed range.

Key words: Bioethanol- Ediesel- Diesohol- Duelfuel- Biofuel- Biodiesel .

1- Introduction

Sunflower methyl ester is a biodiesel. Biodiesel is defined as the mono alkyl esters of long chain fatty acids derived from renewable lipid sources. Biodiesel, as defined, is widely recognized in the alternative fuel industry. Biodiesel is typically produced through the reaction of a vegetable oil or animal fat with methanol in the presence of a catalyst to yield glycerine and methyl esters [1, 2].

The studies on the use of ethanol in Diesel engines can be divided into four techniques. These techniques are the alcohol–Diesel fuel blend using mixture of the fuels prior to injection [3, 4, 5], alcohol fumigation which is the addition of alcohols to the intake air charge [6, 7], alcohol–diesel fuel emulsion i.e. an emulsifier to mix the fuels to prevent separation [3] and dual injection, using separate injection system for each fuel [8].

An advantage of ethanol-diesel fuel blend is that few major component changes are required for their use. There are some difficulties encountered in diesel engines while attempting to use alcohols [7]. The limited miscibility at lower temperatures and required minor variations in fuel delivery systems restrict the use of ethanol in diesel fuel engines [9]. It was determined that the aromatic contents and intermediate distillate temperatures had a significant impact on the miscibility limits [10]. Fuel viscosity and lubricity play significant roles in the lubrication of fuel injection systems, especially for rotary fuel pumps. However, fuel lubricity is not very important in line pumps and unit injectors [11] Small adjustments to the injection timing and fuel delivery may be necessary to restore full power. In this study, no modification on the engine was made for blends.

In a research, the effects of ethanol addition to Diesel No. 2 on the performance and emissions of a diesel engine at full load was investigated. The reductions in torque and power of the engine using 10% and 15% ethanol–diesel emulsion are approximately 12.5% and 20% respectively [12].

In other works, the effects of ethanol fumigation and ethanol-diesel fuel blends on the performance and emissions of a single cylinder diesel engine has been investigated experimentally and compared. The results show that both fumigation and blends methods have the same behavior in affecting performance and emissions,

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[1] Associate professor. Mechanical engineering

[2] ME Mechanical engineering, Tehran, Iran. Phone: 0098-21-44309312 Email: hadi967@yahoo.com

but improvement in using the fumigation method was better than when using blends. The optimum percentage for ethanol fumigation is 20%. This percentage produces an increase of 7.5% in brake thermal efficiency [7].

Another work showed that the thermal balance of the engine operating on 5 and 10% ethanol-diesel blends and fumigated ethanol was not significantly different at 5% level of significance when compared with diesel. However, the thermal balance of the engine operating on 15 and 20% ethanol-diesel blends was significantly different compared to diesel at 5% level of significance [13]. The other experiments performed used 5, 10, 15 and 20% ethanol-diesel blends. The results indicate no significant power reduction in the engine operation on ethanol-diesel blends (up to 20%) at a 5% level of significance. Brake specific fuel consumption increased by up to 9% with an increase of ethanol up to 20% in the blends as compared to diesel alone. The exhaust gas temperature was lower with operations on ethanol-diesel blends as compared to operation on diesel alone [14].

From the available literature regarding the use of biofuel blends in IC engines, it is obvious that one has to overcome the obstacles encountered in actual operating conditions. Understanding and implementing these technical know how and reaching to the solid conclusions was the main objective of the present investigation, the results of which is depicted in the present paper. The actual engine performance is the core objective while using biofuel blends.

2- Materials and methods

The experimental setup consists of a diesel engine, an engine test bed and a gas analyzer. The schematic of the experimental setup is shown in figure (1).

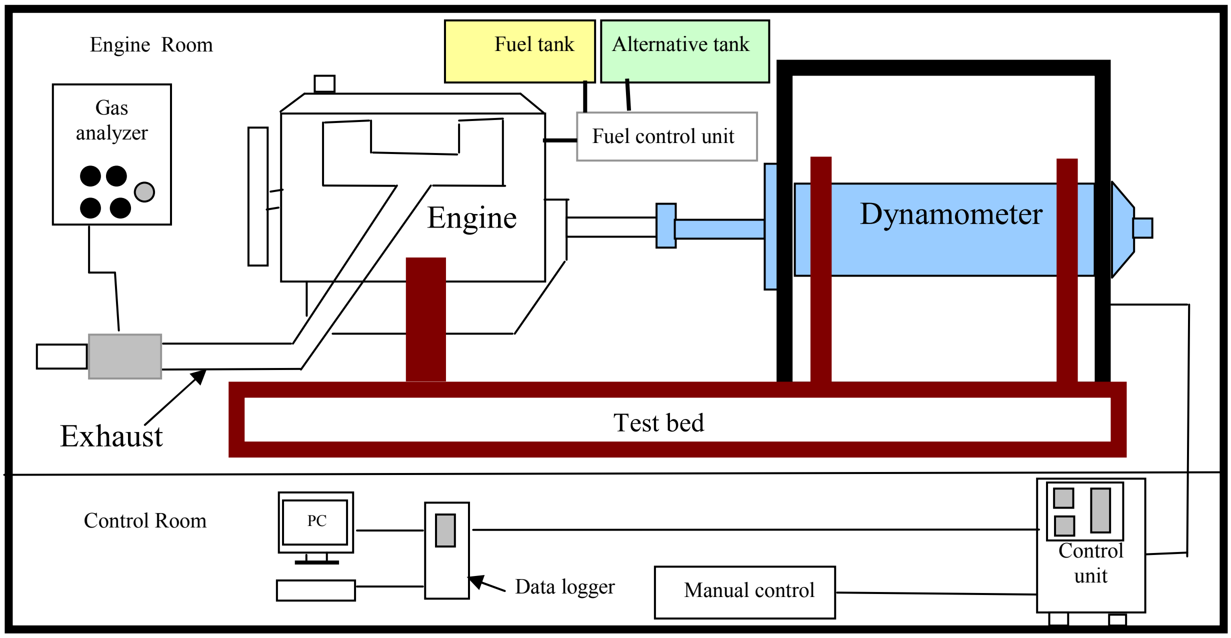

Figure 1: Engine test setup

There are two fuel tanks, one is for diesel fuel and the other for fuel blends. The engine under study is a commercial DI, water cooled two cylinders, in-line, naturally aspirated, RD270 Ruggerini diesel engine whose major specifications are shown in table (1). The test engine was coupled to a Schenck W130 electric eddy current dynamometer. The matrix of experimentation is shown in table (2).

Table 1: Engine Specification

Specifications	No. of cylinder	Cooling system	Bore (mm)	Stroke (mm)	Volume (cc)	Power (hp)	Rated speed (rpm)	Torque (Nm/rpm)	Compression ratio
Value	2	Air cooled	95	85	1205	23.4	3000	67/2300	18:1

Table 2: The matrix of experimentation

S. No.	Parameters	Levels						
		1	2	3	4	5	6	7
1	Speed (rpm)	1200	1600	2000	2400	2800	3200	3600
2	Load (%)	0	100	-	-	-	-	-
3	Bioethanol* (%)	0	3	6	9	12	-	-
4	Methyl ester** (%)	0	2	4	6	8	-	-
5	Diesel fuel (%)	100	95	90	85	80	-	-

* The symbol used for bioethanol is E

** The symbol used for sunflower methyl ester is B

The ethanol produced from potato waste and used in this research work is based on the alcoholic fermentation. Bioethanol and sunflower methyl ester were blended as 60/40 ratio and was added to diesel fuel in 5 to 20 percent ratio s.

3- Results and discussion

3-1 Torque and Power

First of all, fuel rack is placed in maximum fuel injection position for full load conditions. Then, the engine is loaded slowly. The engine speed is reduced in this way with increasing load. Figure 2 shows engine performance at full load conditions using net diesel. The trend of performance curves (power and torque) are very common like those mentioned in valid concerned literature. Range of speed was selected between 1200 – 3600 rpm. Engine test results with net diesel fuel showed that maximum torque was 58.4 Nm which occurred at 2800 rpm. The maximum power was 17.3 kW (23.5 hp) at 3600 rpm. Power and torque for fuel blends at full load is shown in figures (3 - 7). Considering power and torque performance with fuel blends, one can say that the trend of these parameters versus speed is almost similar to net diesel fuel.

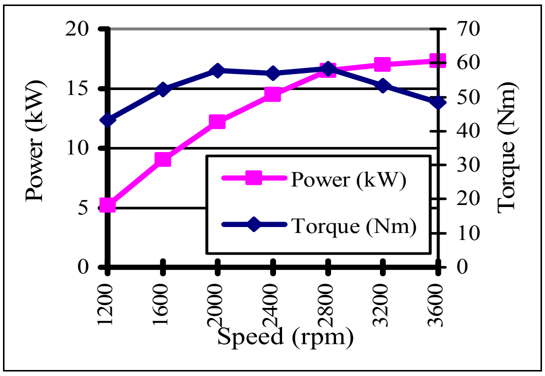

Figure 2: Engine power and torque at full load with net diesel fuel

Figure 3 shows engine performance using $E_9B_6D_{85}$ fuel at full load conditions. The trend of curves in figure (3) exactly resemble those given in figure (2). The maximum torque and power are 56.2 Nm and 16.2 kW (22 hp) at 2400 and 3600 rpm respectively. Maximum torque and power are reduced by 3.8 and 6.4% respectively when adding 9% ethanol and 6% sunflower methyl ester in diesel fuel. A comparison of figures (2 and 3) reveals that while the maximum power is produced at same speed (3600 rpm), the maximum torque produced is shifted from 2800 rpm to 2400 rpm when engine is running on fuel blends instead of net diesel fuel. Similar conclusions are drawn from other fuel blend proportions. Regarding the power reduction when net diesel fuel is being replaced by biofuel blends other researchers have also reached to similar conclusions and reported that maximum power of engine at full load condition is reduced about 5% with adding 10% ethanol in diesel fuel. They reported that lower calorific value of ethanol is one reason for this case. They found that, using additives, the best combustion is occurred and engine performance is improved [4].

The latent heat of vaporization of ethanol is very much higher than net diesel fuel. The latent heat of vaporization of ethanol and diesel fuel is 856 and 280 kJ/kg respectively [4]. After injection of fuel in combustion chamber, first fuel is vaporized. Some amount of energy is needed for vaporization. As a result, the out put energy of ethanol is reduced compared with diesel fuel. Cetane number of almost all the biodiesels is similar to diesel fuel, but cetane number of ethanol is very low [15, 4]. The cetane number of diesel fuel is reduced in directly proportional to the amount of ethanol. Cetane number of diesel fuel is reduced about 7 units with each 10% ethanol addition [4].

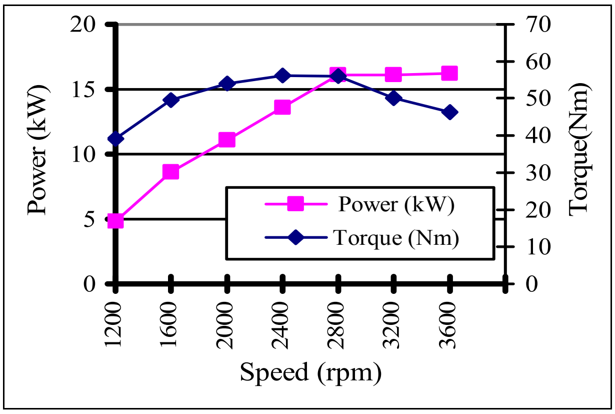

Figure 3: Engine power and torque at full load with $E_9B_6D_{85}$

Figure 4 and table (3) show engine speed and engine power relationship at full load condition using net diesel fuel and fuel blends. The net diesel fuel is used as a base for comparison. The fuel blend behavior is similar to that of net diesel fuel in developing power. Engine produces about 5 kW at 1200 rpm for different blend ratios. The power reaches its peak at 3600 rpm for both net diesel fuel and biofuel blends. A minor reduction in power is observed with fuel blends percentage (figure 5). It means that engine power is reduced with increasing the amount of ethanol and sunflower methyl ester. Other reason for power reduction besides those mentioned for the torque reduction is that, ethanol has lower cetane number (about 5-8) compared with diesel fuel.

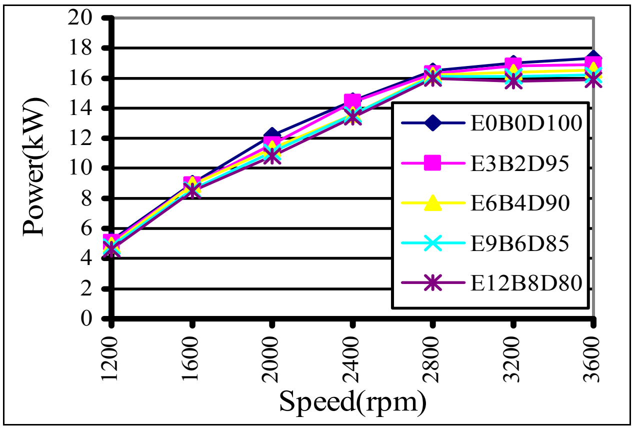

Figure 4: Relationship between engine speed and engine power for different fuel blends

Table 3: Engine power at full load using diesel and fuel blends

	1200	1600	2000	2400	2800	3200	3600*	average
E0B0D100	5.2	9	12.2	14.5	16.5	17	17.3	13.1
E3B2D95	5.1	8.9	11.6	14.39	16.32	16.82	16.9	12.9
E6B4D90	4.9	8.9	11.3	13.58	16.23	16.41	16.53	12.6
E9B6D85	4.8	8.6	11.1	13.6	16.1	16.1	16.2	12.4
E12B8D80	4.6	8.5	10.8	13.4	16	15.8	15.9	12.1

* Maximum engine power at 3600 rpm in all case

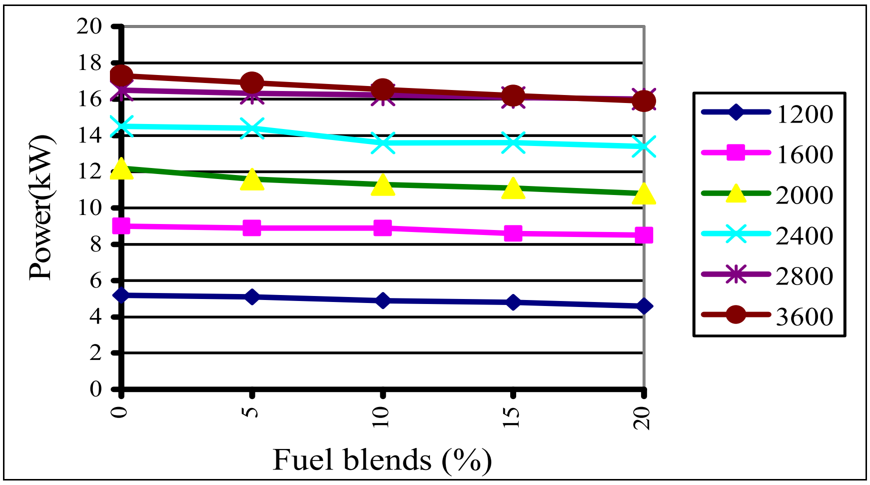

Figure 5: Effect of fuel blends on engine power at full load and different speeds

Figures 6 and 7 and Table 4 show engine torque for all fuels used at full load condition. As shown in this figure, engine torque of diesel fuel at various speeds is higher than other fuel blends. The engine torque is reduced with increasing the percentage addition of ethanol and sunflower methyl ester. The reason is that, the calorific value of ethanol and sunflower methyl ester is lower than net diesel fuel [5]. This trend is considerable with increasing ethanol and sunflower methyl ester percentage. Calorific value of ethanol is about 33 – 44% lower than diesel fuel [15, 16, 4]. Calorific value of biodiesels is also lower than diesel fuel [17]. The lower cetane number and viscosity and higher ignition delay of fuel blends can reduce both engine torque and engine power [12].

The important points and remarks in table (3) and figures (6 and 7) is the speed range for the engine to give the best performance as far as engine torque is concerned. This speed range is the flat portion of speed – torque curves, 2000 – 2800 rpm (figure 6). Fuel blend percentage means the percentage of both bioethanol and sunflower methyl ester present in diesel fuel that varies from 0 to 20 percent (figure 7). A mild decrease in engine torque with increasing fuel blend percentage is expected as explained earlier.

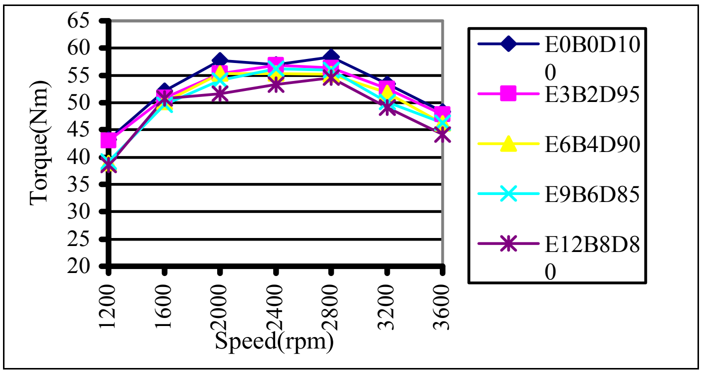

Figure 6: Relationship between engine speed and torque for different fuel blends

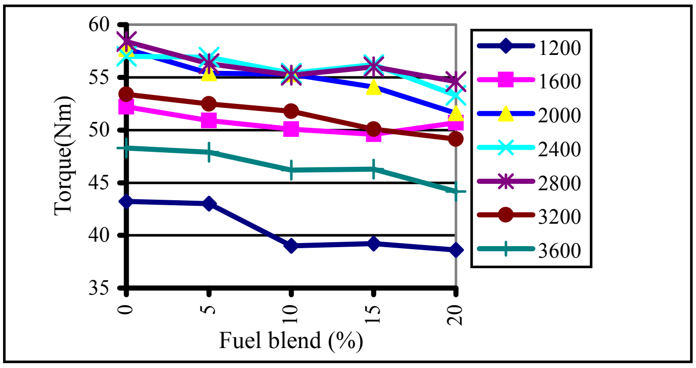

Figure 7: Effect of fuel blends on engine torque at full load and different speeds

Table 4: Engine torque at full load using diesel and fuel blends

Engine speed / Fuel type	1200	1600	2000	2400	2800	3200	3600	average	Reduction (%)
E0B0D100	43.2	52.2	57.7	57	58.4*	53.4	48.3	52.9	0.00
E3B2D95	43	50.9	55.4	56.9*	56.3	52.5	47.9	51.8	2.08
E6B4D90	39	50.1	55.3	55.4*	55.2	51.8	46.2	50.4	4.73
E9B6D85	39.2	49.6	54.1	56.2*	56	50.1	46.3	50.2	5.10
E12B8D 80	38.6	50.7	51.6	53.3	54.6*	49.15	44.18	48.9	7.56

* Maximum engine torque

3-2 Fuel consumption

Engine was run at no load condition i.e. without applying any load and engine fuel consumption was measured. Figure 8 shows the relationship between engine speed and engine fuel consumption at no load. The curves show that fuel consumption is increased with both increasing engine speed and adding ethanol and sunflower methyl ester at no load.

The reasons are that:

- Cetane number of ethanol and hence fuel blend is lower than net diesel fuel.
- Calorific value of ethanol and sunflower methyl ester is lower than net diesel fuel.
- A slight amount of water enters into fuel blends along with ethanol which affects the fuel blend energy content

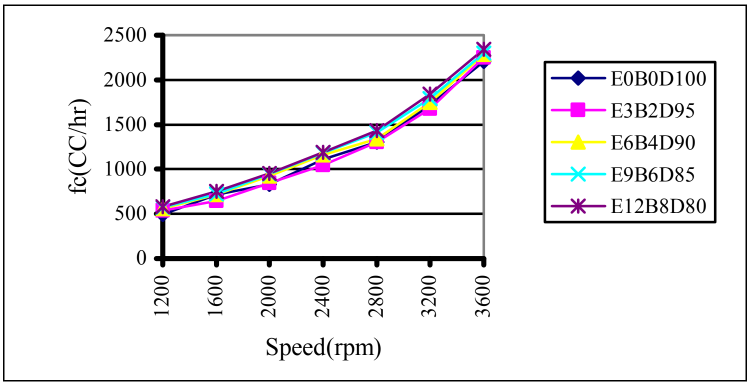

Figure 8: Relationship between engine speed and fuel consumption at full load using different fuel blends

Fuel consumption curves of net diesel fuel at full load are shown in figure (9). The curves show that fuel consumption at full load condition and low speeds is high. Fuel consumption first decreases and then increases with increasing speed. The reason is that, the produced power in low speeds is low and the main part of fuel is consumed to overcome the engine friction. Irrespect of fuel consumption at low speed (1200 rpm), fuel consumption is increased with increasing speed. The reason probably is that, friction power increases with increasing speed.

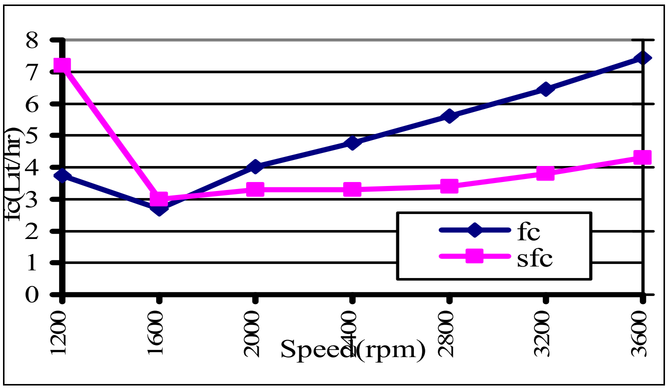

Figure 9: Relationship between engine speed and fuel consumption at full load using net diesel fuel

Figure 10 (a and b) shows fuel consumption with various fuel blends at full load condition. The curves show that fuel consumption is increased with increasing the percentage of ethanol and sunflower methyl ester. This is due to energy content of ethanol and sunflower methyl ester which is lower than net diesel fuel.

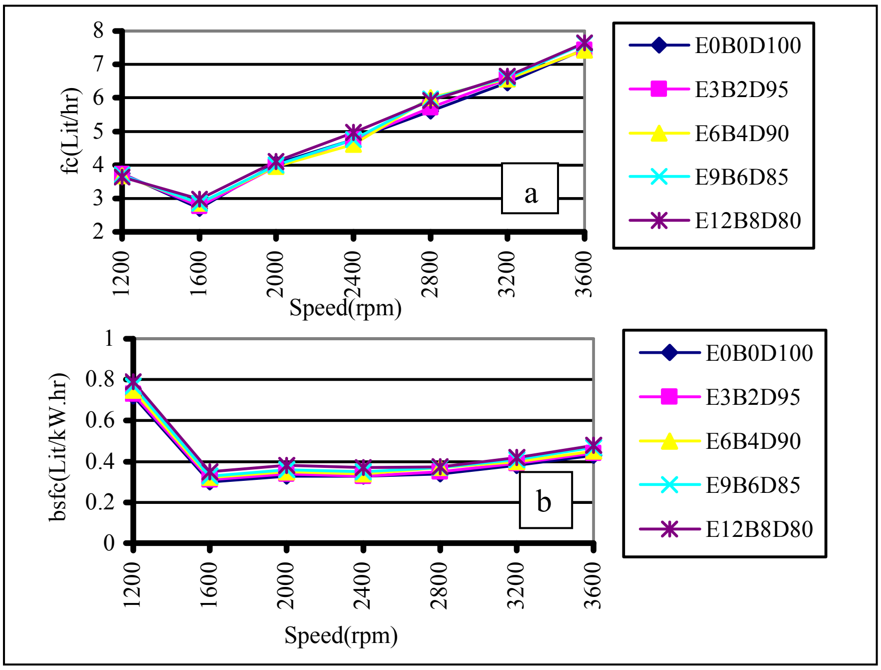

Figure 10 **Relationship between engine speed and : (a) fc, (b) bsfc**

and Figure 11

Table 5 show brake specific fuel consumption with various fuel blend percentage. The curves show that brake specific fuel consumption of fuel blends trends are very similar to net diesel fuel. Brake specific fuel consumption of fuel blends is higher than net diesel fuel. In other words, increasing fuel blend percentage, a mild increase in brake specific fuel consumption is observed.

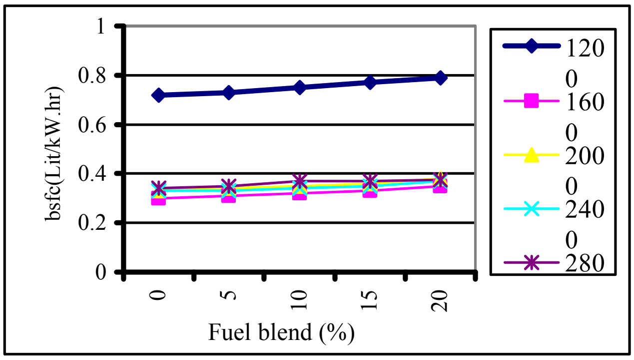

Figure 11 **Effect of fuel blends on bsfc at full load and different speed**

shows increased engine brake specific fuel consumption which is increasing with percentage of fuel blends in comparison with net diesel fuel at full load condition and various speeds. This table shows that mean value of engine specific fuel consumption of 5, 10, 15 and 20% blends for various engine speeds is 2.2, 5.5, 8.3 and 12.1 percent respectively higher than net diesel fuel.

Table 5: Variation of bsfc using fuel blends with respect to diesel fuel

Engine speed / Fuel type	1200	1600	2000	2400	2800	3200	3600	average
E0B0D100*	0	0	0	0	0	0	0	0
E3B2D95	1.4	3.3	3	0	2.9	2.9	2.3	2.2
E6B4D90	4.2	6.7	6.1	3	8.7	5.3	4.7	5.5
E9B6D85	6.9	10	9.1	6.1	8.8	7.9	9.3	8.3
E12B8D 80	9.7	16.6	15.2	12.1	10.3	10.5	11.6	12.1

* The net diesel fuel is taken as a base fuel for comparison

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