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Experimental study of DI diesel engine performance using biodiesel blends with kerosene

A. K. Azad, S. M. Ameer Uddin, M. M. Alam

Department of Mechanical Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh.

Abstract

The experimental investigation offers a comprehensive study of DI diesel engine performance using bio-diesel from mustard oil blends with kerosene. The vegetable oil without trans-esterification reaction have been blended with kerosene oil by volume in some percentage like 20%, 30%, 40% and 50% which have been named as M20 (20% mustard, 80% kerosene), M30 (30% mustard, 70% kerosene), M40 (40% mustard, 60% kerosene) and M50 (50% mustard, 50% kerosene). The properties of the bio-fuel blended with kerosene have been tested in the laboratories with maintaining different ASTM standards. Then a four stroke, single cylinder, direct injection diesel engine has been mounted on the dynamometer bed for testing the performance of the engine using the bio-diesel blends. Several engine parameters like bsfc, bhp, break mean effective pressure, exhaust gas temperature, lube oil temperature, sound level etc. have been determined. A comparison has been made for engine performance of different bio-diesel blends with kerosene with the engine performance of diesel fuel.

Keywords: Diesel engine; Mustard oil; Bsfc; Bhp; Break mean effective pressure.

1. Introduction

The world is presently confronted with the twin crises of fossil fuel depletion and environmental degradation. Indiscriminate extraction and lavish consumption of fossil fuels have led to reduction in underground-based carbon resources [1, 2]. The search for alternative fuels, which promise a harmonious correlation with sustainable development, energy conservation efficiency and environmental preservation, has become highly pronounced in the present context. The fuels of bio-origin can provide a feasible solution to this worldwide petroleum crisis. Gasoline and diesel-driven automobiles are the major sources of greenhouse gases (GHG) emission [3]. Scientists around the world have explored several alternative energy resources, which have the potential to quench the ever-increasing energy thirst of today's population. Various bio-fuel energy resources explored include biomass, biogas, primary alcohols, vegetable oils, biodiesel, etc [4, 5]. These alternative e energy resources are largely environment-friendly but they need to be evaluated on case-to-case basis for their advantages, disadvantages and specific applications [1].

Bio-diesel is the most valuable form of renewable energy that can be used directly in any existing, unmodified diesel engine. Bio-fuels create new markets for agricultural products and stimulate rural development because bio-fuels are generated from crops [6]. In the near future-especially for the two-thirds of the people in the developing world who derive their incomes from agriculture. Due to gradual depletion of world petroleum reserves and the impact of environmental pollution there is an urgent need for suitable alternative fuels for use in diesel engines [7, 8]. In view of this, vegetable oil is a promising alternative because it is renewable, environment friendly and produced easily in rural areas, where there is an acute need for modern form of energy. In recent year's systematic effort have been made by several research workers to use as fuel engines [9, 10].

The several study have been done by using different vegetable oil blends with kerosene to improve the performance of a small type high speed diesel engine under high load condition. They worked with a single cylinder, direct injection, 4-stroke, air cooled, diesel engine applying four blends (20%, 40%, 60% & 80% by volume) of soybean oil with kerosene as well as rapeseed oil with kerosene and compared the results with that of pure diesel fuel [11]. They also studied the spray distribution of each blend in atmosphere used four whole nozzle injector. The result shows that a blend of 20% vegetable oil with 80% kerosene by volume fairly improves the thermal efficiency of the test engine under high load. Therefore, it was recommended to use 20% to 40% vegetable oil blends as a successful alternative. Spray characteristics was studied both under high and low pressure injection in atmosphere where the low pressure injection showed better performance [12, 13].

In Nihon University, Japan, have tested a single cylinder, water cooled diesel engine running with blends of a heavy fuel and low grade oil kerosene for comparison of performance to diesel [14]. The results showed that a mixture of 60% fuel oil and 40% kerosene (by volume) improved thermal efficiency fairly in case of heavy loading for high pressure injection. The experiment was carried out at several injection pressure using three types of injection whole diameter in order to observe the spray distribution and penetration effect in the atmosphere. Small size injector whole diameter of 0.3m at high pressure injection developed a tip velocity of 120 m/s in the atmosphere. High tip velocity is very important for improvement of fuel atomization [13, 14].

Apart from vegetable oils use of alcohol fuels as diesel alternative has been studied widely in many countries. In Japan, has studied the exhaust emission quality and engine performance using various blends of ethanol and diesel, adding kerosene as strong solving agent [13]. Ignition temperature for each blend was measured independently and effect of the blends on engine performance was noted. Ignition temperature of ethanol was the highest whilst ignition temperature of diesel and kerosene were about the same at low level temperature and, therefore, ignition temperature of blend increased as the ethanol percentage in the blend was increased. The result of the experiment showed that although bsfc increased, the thermal efficiency, $N0_X$ and smoke were decreased when ethanol ratio was increased in the blend [13, 15].

The EU continues its reign as the world's largest biodiesel producer, but nearly two-thirds of the region's installed production capacity is currently idle. According to the European Biodiesel Board, the EU produced approximately 9 million metric tons of biodiesel in 2009, while installed capacity measured nearly 22 million tons. Even with this high percentage of unutilized capacity, the EU produced about 65 percent of the world's biodiesel last year [16]. Overall, the EU produced 16.6 percent more biodiesel in 2009 than 2008, although not all areas of the region contributed to this increase. While Austria, Belgium, Finland, Italy, Netherlands, Poland and Spain increased production in 2009, production in Germany, Greece and the UK decreased. Currently, the top three biodiesel producing nations in Europe are Germany, France and Spain. As of July, 245 biodiesel plants exist in the EU, a slight decrease compared to 2008 statistics [17].

Biodiesel can be used to replace petroleum diesel, without requiring modifications to vehicle engines. It can also be blended with conventional diesel at different levels, producing a biodiesel blend. Its main advantages are its high energy yield and its drastically reduced emissions of carbon dioxide (78%); sulfur (100%); carbon monoxide (48%); particulate matter (47%); and hydrocarbon emissions, which form harmful ozone (85%) – resulting in a reduction of 94% in cancer causing potential [14].

Biodiesel outperforms gasoline, ethanol, and conventional diesel in overall fuel efficiency:

Fuel	Energy Yield*	Net energy (loss) or gain
Biodiesel	3.20	220%
Ethanol	1.34	34%
Petro-diesel	0.843	(15.7%)
Gasoline	0.805	(19.9%)

Source: Dekeloil naturally Green Energy.

*expressed in Btus per Btu of fossil fuel energy consumed over its life-cycle.

The global biodiesel market is estimated to reach 37 billion gallons (140 billion liters) by 2016, growing at an average annual rate of over 30%. Europe is expected to continue being the major biodiesel market for the next decade.

2. Properties of bio-fuel

The properties of the pure mustered oil has shown in Table 1. During the test following ASTM standards were maintain and find out the properties of different bio-fuel blends. The below table has shows the properties at room temperature. The properties of different bio-diesel blends have been tested at different temperature which has discussed later.

Table 1. Properties of pure mustard oil

SL. No	Property and Standards	Unit	Value
1	Density @ 31°C (ASTM D4052-11)	kg/m^3	925.24
2	Specific Gravity (ASTM D5453-09)	-	0.941
3	Kinematic Viscosity @ 31°C (ASTM D2161-79)	mm^2/sec	63.40
4	Dynamic Viscosity @ 31°C (ASTM D7042-11a)	cP	58.66
5	Calorific Value (ASTM 2382)	MJ/Kg	39.51
6	Carbon Residue (ASTM D189-81)	gm	0.037
7	Carbon Residue (ASTM D189-81)	%	0.37
8	Flash Point (ASTM D93-85)	°C	310
9	Fire Point (ASTM D92-11)	°C	350

Figure 1 shows the color of different bio-diesel blends with kerosene from left to right B20, B30, B40, B50, B100/pure mustard oil, and at last pure diesel respectively. The properties of these bio-fuel blends have been tested in the fuel tasting laboratories. The test results have been shown in Table 2.

M20 M30 M40 M50 Pure Mustard Pure Diesel

Figure 1. Sample color of different bio-diesel blends with kerosene, pure mustard and diesel

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Table 2. Properties of different bio-fuel blends, mustard oil and pure diesel

Properties and Standards	Unit	Value for different bio-fuel blends				B100 or	Pure
		M20	M30	M40	M50	Mustard	Diesel
Density 31°C (ASTM D4052-11)	kg/m^3	826.8	837.2	852.6	860.84	925.24	825.9 6
Specific Gravity (ASTM D5453-09)	-	0.895	0.903	0.912	0.917	0.941	0.899
Kinematic Viscosity 22°C (ASTM D2161-79)	mm^2/sec	2.68	4.45	6.87	9.16	63.40	3.96
Dynamic Viscosity @ 22°C (ASTM D7042-11a)	cP	2.21	3.79	5.85	7.88	58.66	3.27
Calorific Value (ASTM 2382)	MJ/Kg	42.8	40.5	38.0	35.96	39.51	44.00
Flash Point (ASTM D93-85)	°C	45	50	55	65	310	72
Fire Point (ASTM D92-11)	°C	55	60	70	80	350	210

The calorific value or heating value is very much important property of the fuel. The calorific value or heating value indicates the energy density of the fuel. In this study, ASTM 2382 method has been applied to measure the heating value of biodiesel and their blends with kerosene. Table 2 shows the heating value of diesel, mustard oil and their blends with kerosene in MJ/Kg. The variation of calorific value has been obtained in Figure 2, which has been shown that, diesel fuel has heating value about 44 MJ/Kg, pure mustard oil has 32.43 MJ/kg and kerosene has 43.10 MJ/kg. Heating values of the fuel decreases as we choose higher blending of bio-fuel with kerosene because the pure mustard oil has lower heating value.
Figure 3 has shown the density of different bio-fuel blends with kerosene at different temperature. The M20 has lower density and the pure mustard has higher density. The density increases with the increase of bio-fuel blends but little density variation between M40 and M50. Density of the fuel is an important property for IC engine. Higher density fuel required preheating for ignition So, the engine intake manifold should be redesigned so that preheating can be done utilizing the exhaust of the engine.

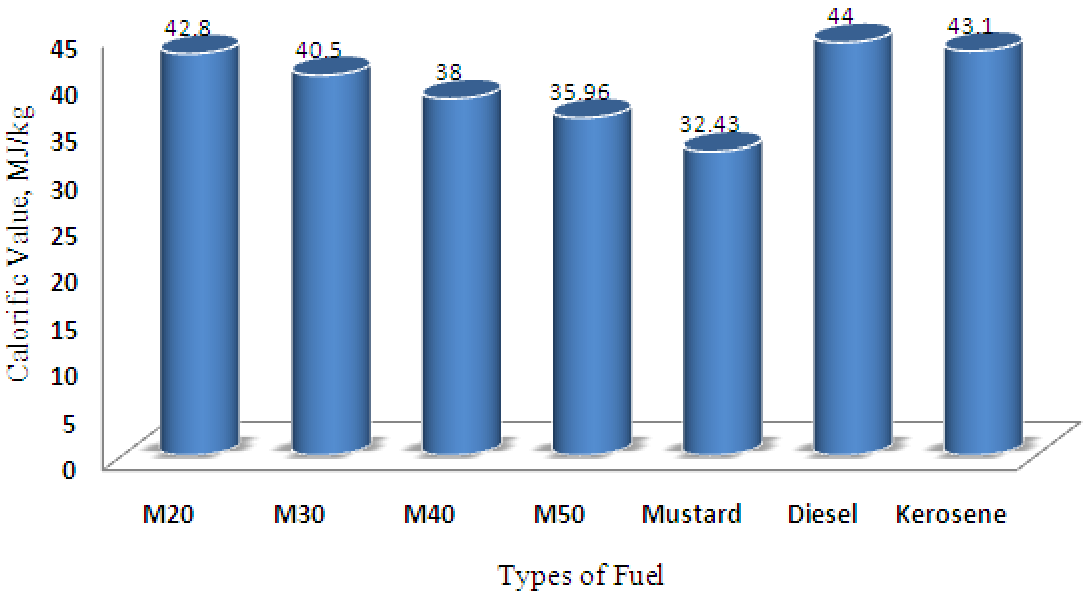

Figure 2. Lower calorific value in MJ/kg for different blends

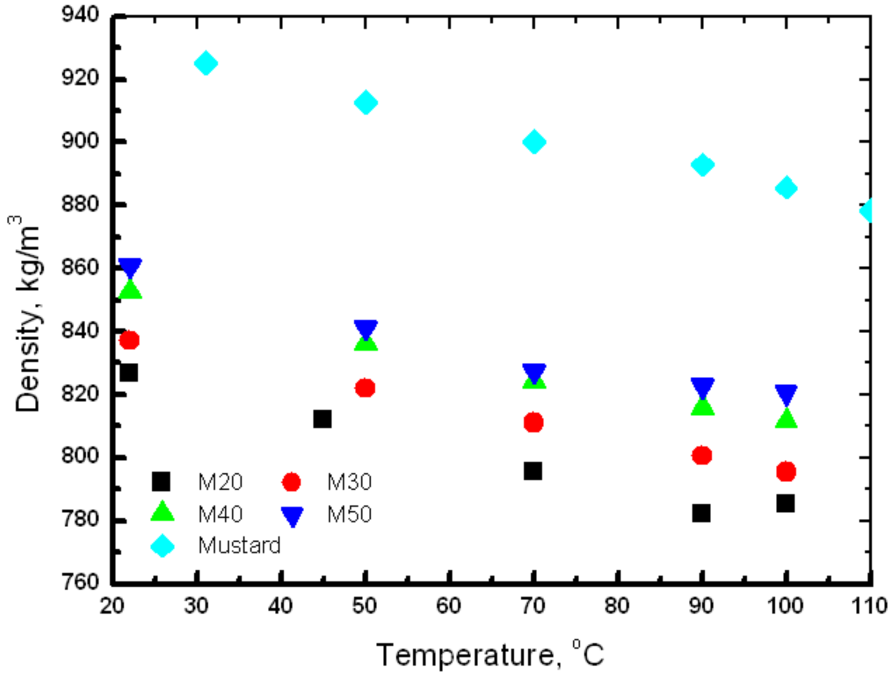

Figure 3. Variation of density with temperature for the different bio-fuel blends with kerosene.

Figure 4 represents the variation of dynamic viscosity of the fuel blends with different temperature. It has been shown that viscosity increases with the increase of bio-diesel blends. But at higher temperature the viscosity of M20 and M30, M40 and M50 becomes closer to each other than lower temperature and it is about 2.5 times higher than the fossil diesel at room temperature. Higher viscosity caused poor atomization and slow rate of burning of bigger droplets and consequently longer ignition delay. To improve the atomization preheating of crude oil and to improve the ignition quality addition of an ignition enhancer was suggested. Alternatively, increase of injection pressure with some modification of nozzle hole was also suggested to improve the ignition property. Increase in injection pressure increases the engine speed which, in turn, changes the temperature/time and the pressure/time relationships and, therefore, decreases ignition delay.

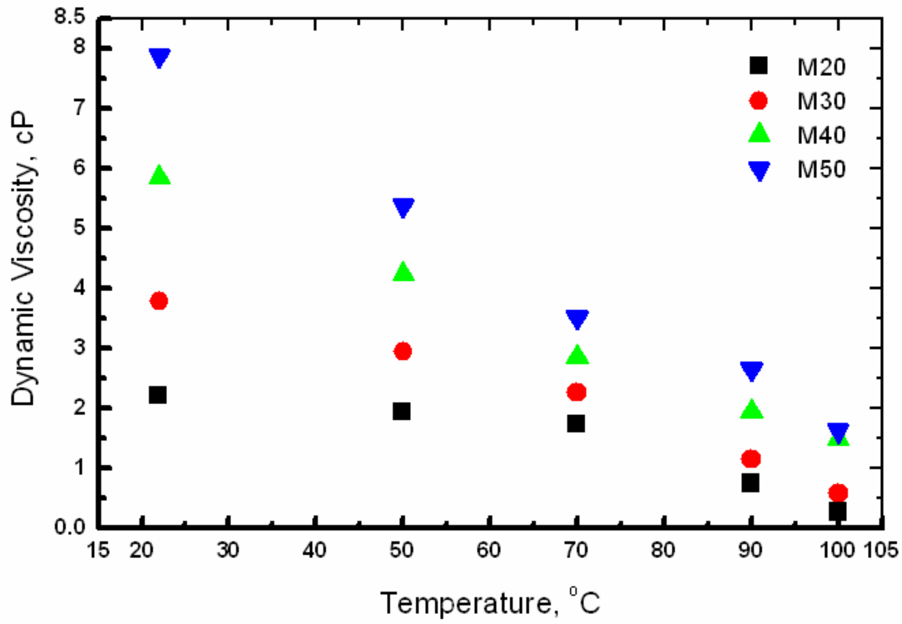

Figure 4. Variation of dynamic viscosity with temperature

3. Experimental setup

In this experiment a single cylinder, water-cooled, 4- stroke, and DI diesel engine (specification Table 3) has been used for performance testing. The RPM was measured directly from the tachometer attached with the dynamometer. The fuel injection timing was set at 24°BTDC. The dynamometer specification has shown in Table 4.

Table 3. Test diesel engine specifications

SL.	Items	Engine Data
1.	Model	S195G
2.	Method of starting	Hand starting
3.	Engine Type	Single cylinder, 4-stroke, Horizontal, Direct Injection
4.	Cylinder Bore	95 mm
5.	Piston stroke/ Stroke	115 mm
6.	Swept Volume	85 cc
7.	Nominal speed	2000 rpm, Anti-clockwise
8.	Nominal power	9 KW
9.	Compression ratio	1:20
10.	Specific fuel consumption	Less or equal 258.4 gm/kw-hr or 192.76 gm/BHP-hr
11.	Cooling system	Water cooled condenser type, Thermosyphon with suction fan
12.	Fuel and Lube oil filter	Present

Table 4. Dynamometer Specification

SL.	Items	Data
1.	Dynamometer: Model	TFJ-250L
2.	Max. braking horsepower (PS)	250
3.	Revolutions at max. braking horsepower point (rpm)	2500 to 5500
4.	Max. braking torque (kg.m)	71.6
5.	Max. revolutions (rpm)	5500
6.	Max. Braking water quantity (Lit/min.)	75
7.	GD (Kg. m^2)	0.25
8.	Weight(Kg)	575
9.	Main bearings	Ball and roller bearings drip-feed

Figure 5, has shown the schematic diagram of the experimental setup with its essential parts. The test engine coupled with dynamometer bed has shown in Figure 6. Water brake type dynamometer from Tokyo Meter Co. Ltd of model no.TFJ-250L was used for simulating artificial loads and testing engine performances. The dynamometer varied the load on the engine using variable water flow as well as variable impeller blade angles. A non-contact magnetic induction tachometer and a Wheatstone bridge load cell were used for speed and torque measurements.

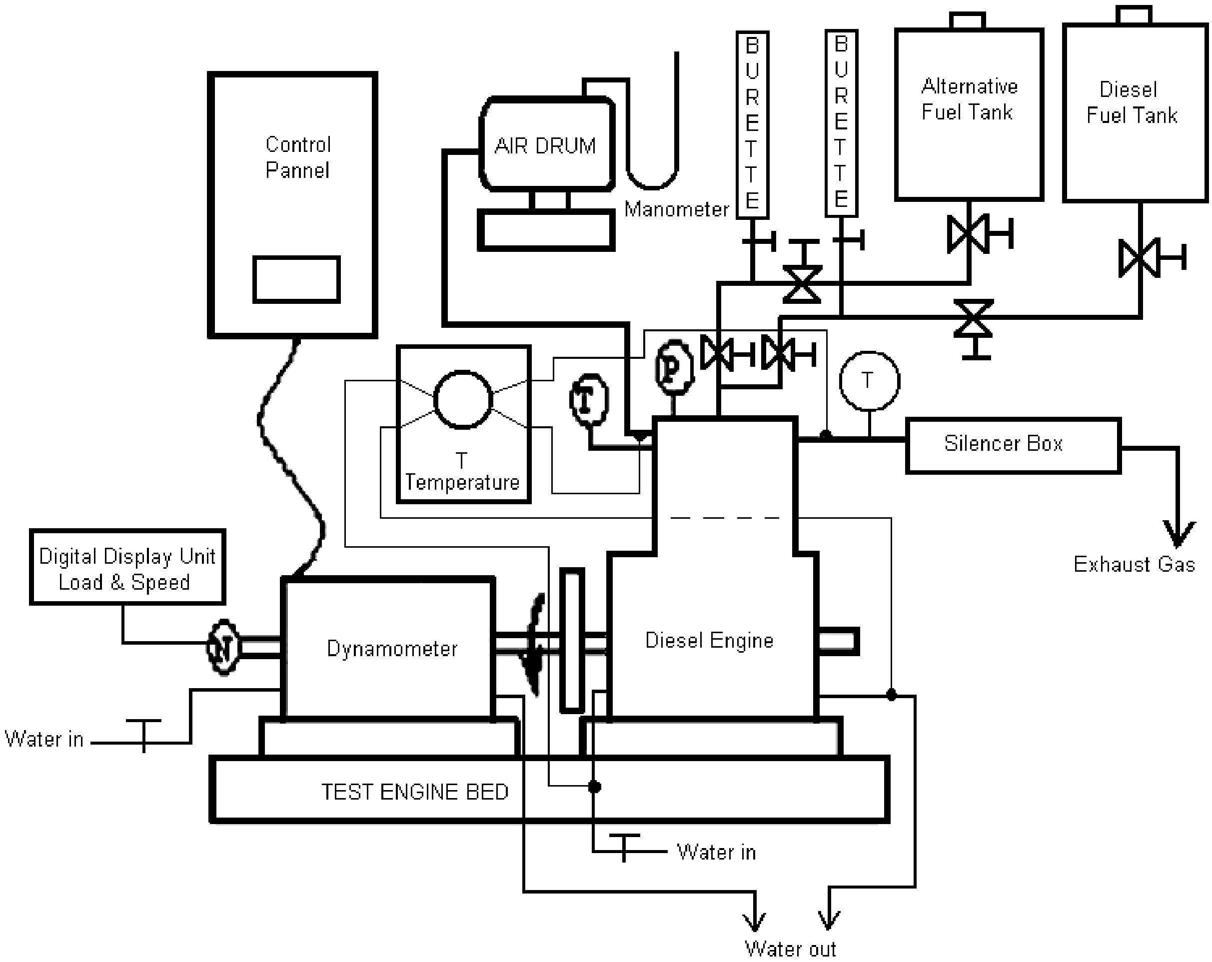

Figure 5. Schematic diagram of the experimental setup with hydraulic dynamometer

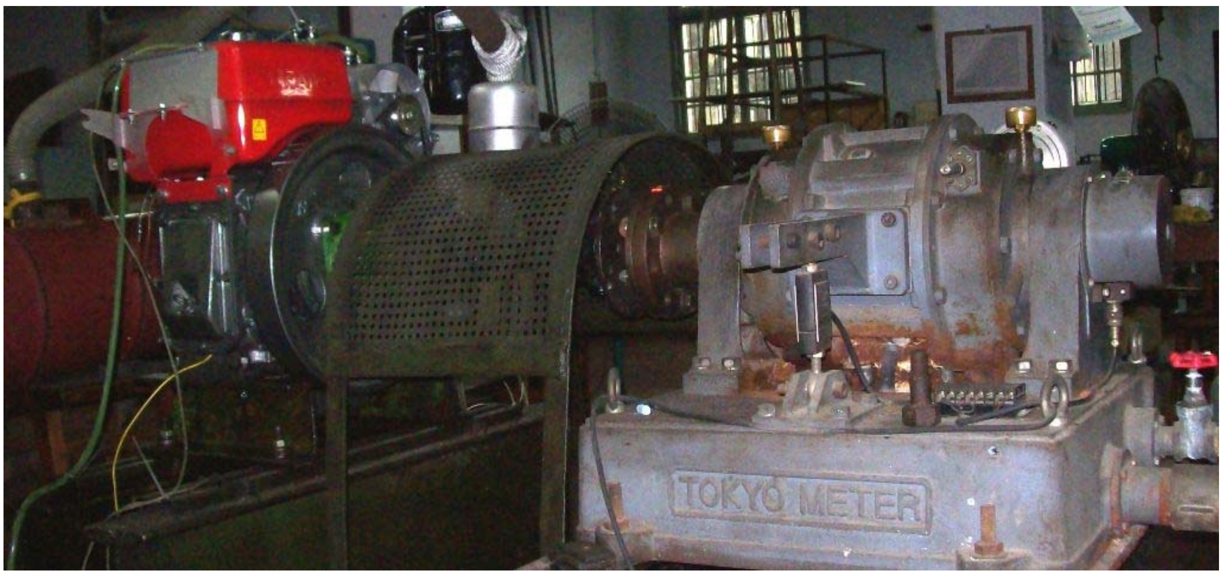

Figure 6. Test engine mounted on dynamometer bed

4. Results and discussions

The engine performance has been tested by the different bio-fuel blends both in lab condition and BS (British Standard) condition. The findings of the engine performance has been discussed below.

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Figure 7, has shown the variation of break specific fuel consumption (bsfc) with engine load i.e. bhp for different bio-fuel blends with kerosene. The break specific fuel consumption (bsfc) was calculated as fuel consumption divided by rated power output of the engine. The curve shows that bsfc is higher at low load and decreases with the increase of load for different bio-diesel blends. It also has been shown that the bsfc increases with the increase of bio-diesel blends i.e. M20 to M100. This is mainly due to the relationship among volumetric fuel injection system, specific gravity, viscosity and heating value of the fuel. As a result, more biodiesel blend is needed to produce the same amount of energy due to its higher density and lower heating value in comparison to conventional diesel fuel. Again as biodiesel blends have different viscosity, so biodiesel causes poor atomization and mixture formation and thus increases the fuel consumption rate to maintain the power. Lowest bsfc is obtained for M30 (116.5 gm/bhp-hr) at 13.22 bhp. The second minimum bsfc obtained for M20 (164.9 gm/bhp-hr) at 12.58 bhp load. But height bsfc has been obtained for M100/ pure mustard oil in every condition. In higher load condition bsfc for every blend becomes closer to each other.

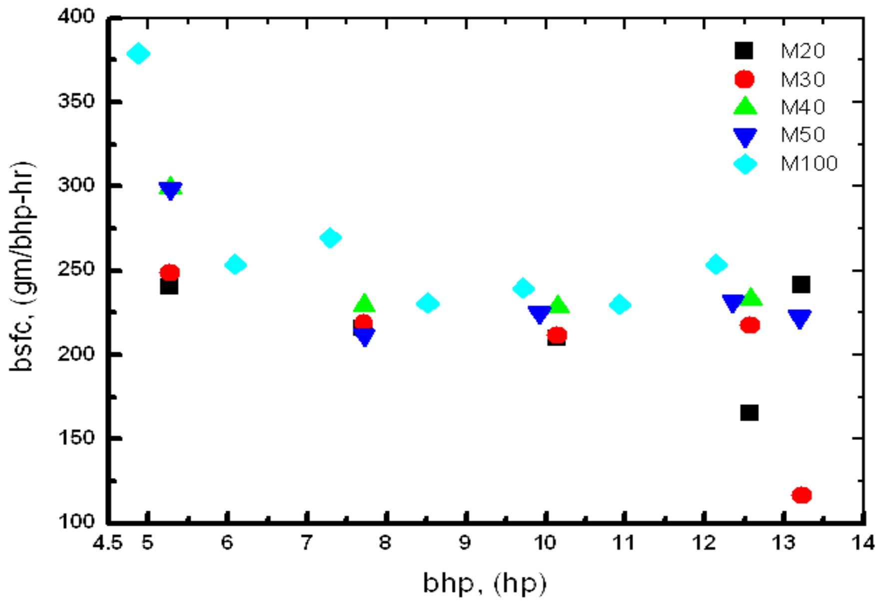

Figure 7. Variation of break specific fuel consumption (bsfc) with break house power (bhp)

The bsfc is a measure of overall efficiency of the engine. It’s also inversely proportional to the thermal efficiency. So, the lower value of bsfc indicates the higher of overall efficiency of the engine. Figure 8, has shown the variation of break thermal efficiency with engine load. The break thermal efficiency of the engine was observed to increase with increase in the load and decrease with the increase of bio-fuel blends with kerosene. The better result has been found overall thermal efficiency for M20. But the maximum bte was found for M30 (51.15%) at 13.22 bhp load.

The mean effective pressure is the average pressure developed on the piston head over a cycle in the combustion chamber of the engine which measures the capacity of the engine to do work. Figure 9 has shown the variation of break mean effective pressure for different bio-fuel blends. A little variation of mean effective pressure has been observed during the experiment for each blend. The bmep gradually increase with the increase of engine load and the height bmep was obtained at 13.22 bhp load for each blends. The regular shape of the curve indicates that the proper combustion has done in the combustion chamber of the fuel.

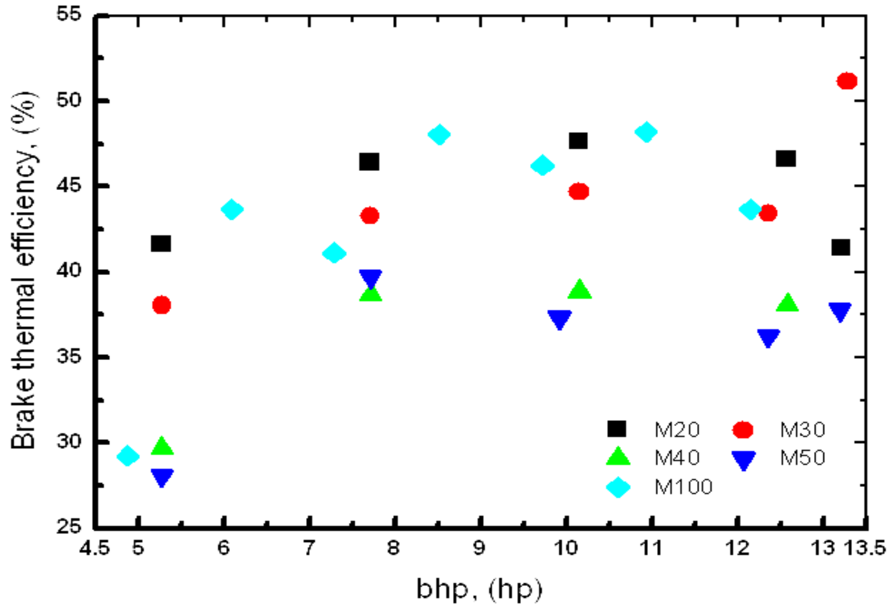

Figure 8. Variation of break thermal efficiency with break house power (bhp)

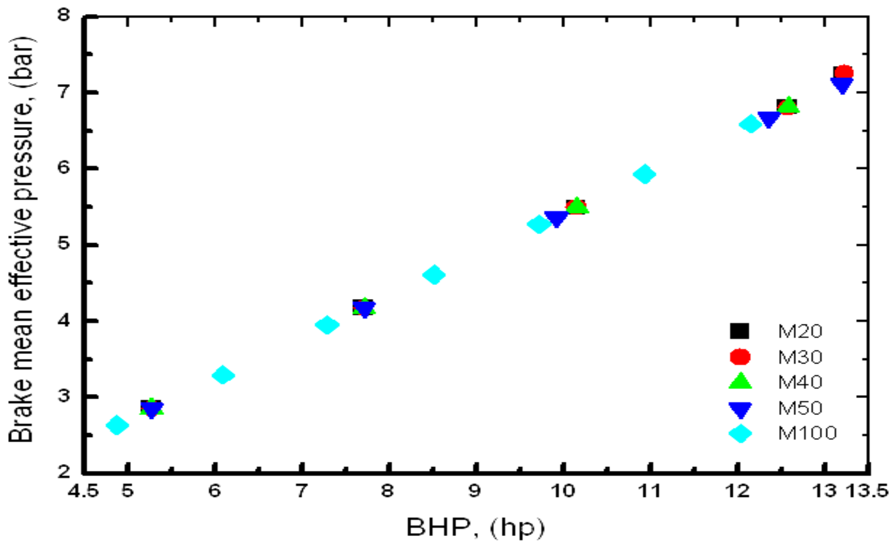

Figure 9.Variation of break mean effective pressure with engine load

Figure 10, represents the variation of exhaust gas temperature with engine load for different fuels. From the curve it has been observed that initially the exhaust gas temperature is lower and little variation to each other. For M100 or pure mustard oil, have higher exhaust gas temperature than all other biodiesel blends. At starting condition, higher exhaust gas temperature but low power output for biodiesel blends indicate late burning to the high proportion of biodiesel. This would increase the heat loss, making the combustion a less efficient. At higher load condition, M40 has lower exhaust temperature as compared to other fuels. During the experiment it has been observed that the test engine becomes wormer earlier with the increased of bio-fuel blends. In the case of pure mustard oil the engine have more knocking and black smoke dispatch with its exhaust gas. Its needed preheated because of its higher density, viscosity and lower atomization capacity and would require some modify of the fuel supply system.

Figure 11 shows the relation in between lube oil temperature and engine load for different fuel and bio-fuel blends. The lube oil temperature increases with the increase of engine load and higher lube oil temperature has shown for M20 at full load condition than any other blends. But for pure mustard oil lube oil temperature becomes lower at lower load condition because of its more lubricity property. But at higher load M50 shows minimum lube oil temperature than other blends.

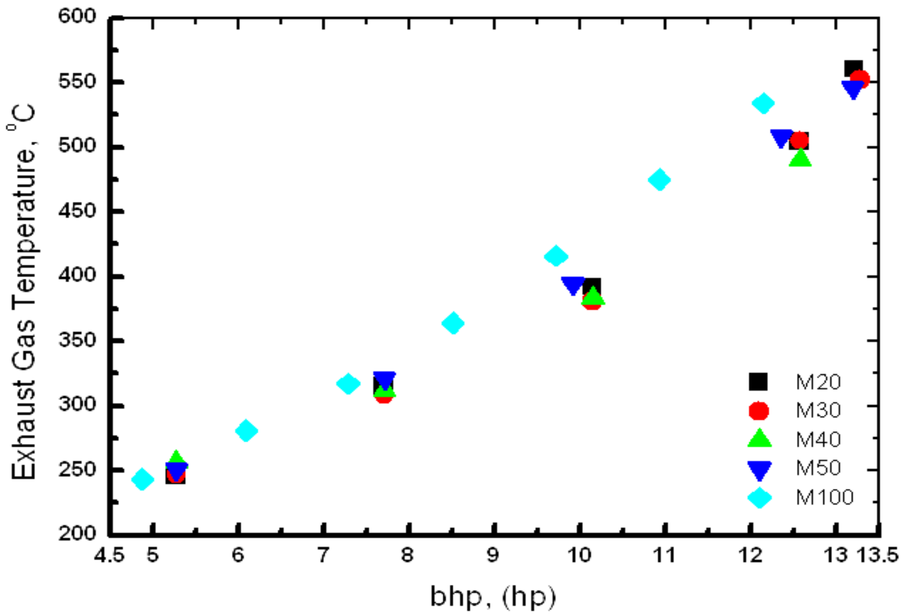

Figure 10.Variation of exhaust gas temperature with engine load

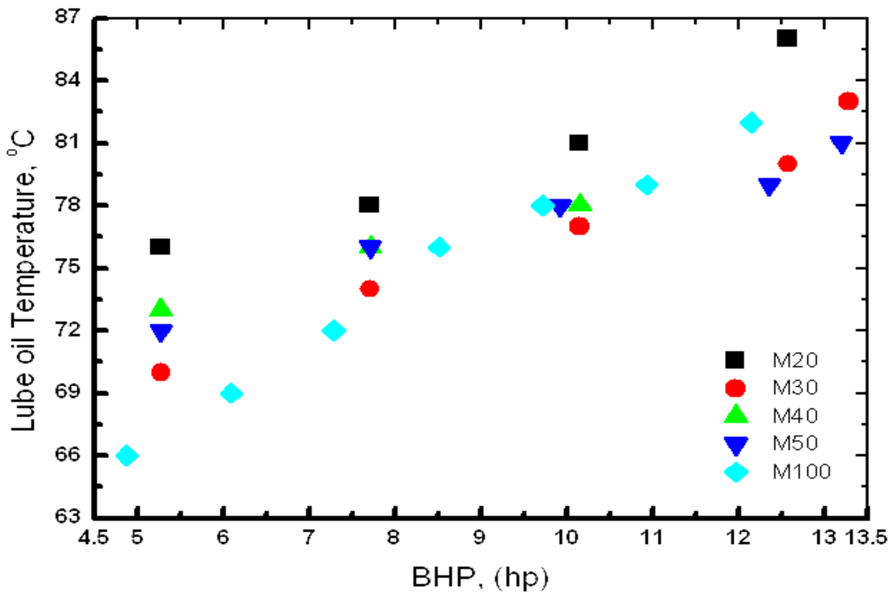

Figure 11.Variation of engine lube oil temperature with load

5. Advantages of bodiesel

From the above results and discussions the following advantages have been drown to use bio-diesel in replace of conventional fossil fuel.

According to USA Department of Energy and Department of Agriculture lifecycle emissions studies have shown that 78% reduction of Carbon dioxide (CO2) emissions by using bio-diesel. Thus biodiesel (B100, i.e., 100% biodiesel) dramatically reduces emissions, as compared with conventional, petroleum-based diesel. Because biodiesel is produced from plants, these plants had been absorbing carbon dioxide when they were still growing in the field. When taking into account both carbon dioxide absorptions and later carbon dioxide emissions, the overall life-cycle result is a significant lowering of carbon dioxide emissions, as compared with both petroleum-based diesel and gasoline. Biodiesel thus helps combat global warming.

a) Biodiesel is biodegradable.
b) Blended biodiesel fuel, such as B20, reduces carbon dioxide emissions by 15% (based on USA Department of Energy data).

c) Biodiesel has a high ignition point (175°C/350°F vs. -42°C/-43°F for gasoline), and is therefore a safer fuel.
d) Blended biodiesel can be used in existing diesel engines, requiring little or no modifications.
e) Biodiesel is better for vehicle engines than conventional diesel: it provides greater lubrication and also leaves fewer particulate deposits behind.
f) Biodiesel dramatically reduces engine wear and is much less caustic to mechanics.
g) Biodiesel mixes easily with petroleum diesel, and has higher cetane, similar power and torque and meets ASTM standards.
h) Biodiesel can be distributed utilizing existing fuel distribution infrastructure.
i) Biodiesel is considered nontoxic by the USA Environmental Protection Agency.
j) Biodiesel is used for oil spill cleanup.

6. Cost analysis

The present costing of running a diesel engine with biodiesel blends with kerosene oil are given in Table 5.

Table 5. Cost of running engines with different fuels

Fuel	*Cost per Liter of fuel*		
	Local Market	International Market	
	BDT (TK)	USD ($)	EURO (€)
Diesel	54.78	0.85	0.67
M20	77.14	1.12	0.88
M30	87.98	1.23	0.97
M40	98.83	1.34	1.05
M50	109.68	1.45	1.14
M100	163.92	2.00	1.57

According to money market on Friday, 18 May, 2012 **(**1 USD = 81.9672 BDT and 1 EUR = 104.1877 BDT). The cost of the bio-fuel blends based on the international fuel market price on the above mentioned date. According to international fuel market $0.90 per liter kerosene and $ 0.85 per liter diesel on 15th May, 2012.

From Table 5, it has been clear that; diesel engine running with biodiesel blends with kerosene is costly as compared to diesel fuel. Though the cost of methanol for the trans-esterification reaction has absolutely zero because, the mustard oil has been directly blends with kerosene oil without chemical reaction. Moreover, in the experiment food grade mustard oil have used. The using of raw or unprocessed oil would also cause to decrease the biodiesel production cost.

In Bangladesh, government grants a huge subsidy on diesel fuel and kerosene, which causes the lower price for diesel fuel. So, the international market price per liter of diesel and bio-diesel blends with kerosene has shown in the Table. It has been recommended that a thorough study has required for the feasibility analysis of biodiesel by comparing it production cost with international market price of diesel.

7. Economic impact

Multiple economic studies have been performed regarding the economic impact of biodiesel production. One study, commissioned by the National Biodiesel Board, reported the 2011 production of biodiesel supported 39,027 jobs and more than 2.1 billion dollars in household income. The growth in biodiesel also helps significantly increase GDP. In 2011, biodiesel created more than 3 billion dollars in GDP. Judging by the continued growth in the Renewable Fuel Standard and the extension of the biodiesel tax incentive, the number of jobs can increase to 50,725, 2.7 billion dollars in income, and reaching 5 million dollars in GDP by 2012 and 2013.

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8. Conclusion

In regard to the experimental study the following conclusions are drawn

- The bio-fuel can be produced from mustard oil blended with kerosene without transesterification reaction as an alternative fuel for DI diesel engine.
- The calorific value of the bio-fuel blends decreases with the increase of mustard oil percentage and lowest heating value was obtained for M100 or pure mustard oil.
- At starting condition or low load condition the bio-fuel blends have higher bsfc. The bsfc decreases with the increased of engine load. M20 and M30 have approximately closer characteristics at lower load and obtained lower bsfc than any other fuel in the experiment.
- The break thermal efficiency for M20 has becomes better than other fuel blends at this engine operating condition and would better performance compare with M30.
- The lube oil temperature decreases with the increase of bio-diesel blends except and height lube oil temperature obtained for M20 but exhaust gas temperature increases with the increase of bio-diesel blends.
- A little variation of mean effective pressure was observed for different bio-diesel blends from diesel fuel.
- Through the experiment M20 and M30 have better performance than other bio-fuel blends. Though M20 have lower lubricity property but its better blend then M30.
- Finally, it can be possible to run diesel engine with mustard and kerosene oil blends without any modification of the engine.

References

[1] Radha, K. K., Sarada1, S. N., Rajagopal, K., and Nagesh, E. L., (2011), "Performance and Emission Characteristics of CI Engine Operated On Vegetable Oils as Alternate Fuels", International Journal of Automotive and Mechanical Engineering, Vol. 4, pp. 414-427.

[2] Kumar, S., Chaube, A., and Jain, S. K., (2012), "Experimental investigation of C.I. Engine Performance Using Diesel Blended with Jatropha Bio-diesel", International Journal of Energy and Environment, Vol.3, Issue.3, pp. 471-484.

[3] Nakpong, P. and Wootthikanokkhan, S., (2010), "Optimization of biodiesel production from Jatropha curcas L. oil via alkali-catalyzed methanolysis", Journal of Sustainable Energy & Environment, Vol.1, pp. 105-109.

[4] Forhad, A., Rowshan, A. R., Habib, M. A., and Islam, M. A., (2009), "Production and Performance of Biodiesel as an Alternative to Diesel," International Conference on Mechanical Engineering.

[5] Berchmans, H. J., Hirata, S., (2008), "Biodiesel production from crude Jatropha curcas L. seed oil with a high content of free fatty acids", Bioresource Technology, Vol.99, pp.1716–1721.

[6] Radwan, M. S., Ismail, M. A., Elfeky, S. M. S., and Abu- Elyazeed, O. S. M., (2007) "Jojoba methyl ester as a diesel fuel substitute: Preparation and characterization", Applied Thermal Engineering, Vol. 27, pp.314–322.

[7] Lin, C.Y., Chen, L.W., and Wang, L.W., (2006), "Correlation of black smoke and nitrogen oxides emissions through field testing of in-use diesel vehicles", Environmental Monitoring and Assessment, Vol. 116(1-3): pp.291-305.

[8] Naik, M., Meher, L.C., Naik, S.N. and Das, L.M., (2008), "Production of biodiesel from high free fatty acid Karanja (Pongamia pinnata) oil", Biomass and Bio-energy, Vol. 32, pp.354-357.

[9] Khan, M.Y., Khan, S.Y., and Ahmad, N., (2006), "Performance characteristics of compression ignition engine when operated on preheated Neem oil", Proceeding of International Conference on Advances in Mechanical Engineering, Punjab, Dec 1-3.

[10] Altan, R., Cetinkay, S.,and Yucesu, H. S., (2001), "The potential of using vegetable oil fuels as fuel for diesel engines", Energy Conversion and Management, Vol.42, Issue.5, pp. 529-538.

[11] Ghormade, T. K., and Deshpande, N. V., (2002), "Soybean oil as an alternative fuels for I. C. engines", Proceedings of Recent Trends in Automotive Fuels, Nagpur, India.

[12] Kumar, and Reddy, V. K., (2000), "Experimental investigations on the use of vegetable oil fuels in a 4-stroke single cylinder diesel engine", Ph.D Thesis, submitted at JNTU, Anantapur.

[13] Huzayyin, A. S., Bawady, A. H., Rady, M. A., and Dawood, A., (2004), "Experimental evaluation of Diesel engine performance and emission using blends of jojoba oil and Diesel fuel", Energy Conversion and Management, Vol.45, pp.2093–2112.

[14] Narayan, C.M., (2002), “Vegetable oil as engine fuels— prospect and retrospect”, Proceedings on Recent Trends in Automotive Fuels, Nagpur, India.
[15] Srivasata, A., and Prasad, R., (2000), “Triglyceride based diesel Fuels,” Renewable and sustainable Energy Reviews, vol. 4, No. 2, pp. 111-133.
[16] Yosimoto, Y., Onodera, A., and Tamaki, H., (2001), “Production and Emission Characteristics of Diesel Engine Fuelled by Vegetable Oils,” The Society of Automotive Engineers, No. 2001-01-1807/4227.
[17] Ramadhas, A.S., Jayaraj, S. and Lakshmi Narayana Rao, K. 2002. Experimental investigation on non edible vegetable oil operation in diesel engine for improved performance. National Conference on Advances in Mechanical Engineering, J.N.T.U., Anantapur, India.

Abul Kalam Azad was born on 10th August, 1984. He has done Master of Science in Mechanical Engineering from Bangladesh University of Engineering and Technology (BUET); Dhaka, Bangladesh, in the year 2010. He has more than 23 papers that have been published in different international journals and conferences proceedings. His areas of interest are renewable energy, computational fluid dynamics and its application, heat and mass transfer, bio-fuel, natural gas processing and oil refinery, Global energy and environmental issue. Presently, he is working in Bangladesh Oil, Gas and Mineral Corporation (Petrobangla) under the ministry of power, energy and mineral resources. He is a member of the institute of engineers, Bangladesh (IEB) and also member of Bangladesh Society of Mechanical Engineers (BSME).
E-mail address: azad_sgfl@yahoo.com

S. M. Ameer Uddin received the B. Sc Engineering degree (Mechanical) from Chittagong University of Engineering and Technology (CUET), Dhaka, Bangladesh. He has done Master of Science in Mechanical Engineering from Bangladesh University of Engineering and Technology (BUET); Dhaka, Bangladesh, in the year 2012. He has more than 3 papers that have been published in different international journals and conferences proceedings. His areas of interest are renewable energy, heat and mass transfer, bio-fuel, and automobile engineering. Presently, he is working in Bangladesh railway.
E-mail address: sumonbd.ameer@gmail.com

Muhammad Mahbubul Alam received the B. Sc Engineering degree (Mechanical) from Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh in 1983 and joined as a Lecturer in the Department of Mechanical Engineering at BUET in the same year. He did his M. c Engineering degree from the above University (Thesis: Analysis of Yaw Stability of HAWT) and obtained the Ph.D degree in Mechanical Engineering from the (Thesis: Wind-driven Rotodynamic Pumps for Low-lift Applications) University of Reading, UK in 1994. He is now a professor in the Department of Mechanical Engineering at BUET, also served as the Head of the same Department at BUET for 2 years. He is also a part-time teacher at the Military Institute of Science and Technology (MIST), Dhaka. He has published more than 40 papers in national and International Journals and in Conference Proceedings. His research interest include: Wind Energy, Conventional and Renewable Energies (management, policy and environmental issues) Automobiles (Trends, congestion and hazards. More at www.buet.ac.bd./me/faculty/mahbubul/index.html.
E-mail address: mail@mail.com