Effect of Injection Pressure on the Performance and Emission Characteristics of DI Diesel Engine Fueled with Fish Oil Methyl Ester (FOME) - Blended Diesel Fuel

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Abstract:- **Rising fuel costs and impending emissions regulations have sharpened the automotive industry's focus on efficiency. The availability of petroleum is also uncertain in future. Fast depletion of fossil fuels is demanding an urgent to carry out research work to find viable alternative fuels. To cut foreign exchange and contribute towards protection of earth from the threat of environmental degradation, bio-fuels can be a good alternative for diesel for most of the developing countries. Vegetable oils and animal fats have considerable potential to be considered as appropriate alternative as they possesses fuel properties similar to that of diesel. The main objective of this work is to study the influence of injection pressure on the performance and emission characteristics of a DI diesel engine using Fish Oil Methyl Ester (FOME)-blended diesel fuel. The tests were conducted on a single cylinder, water cooled, four stroke direct injection diesel engine with varying injection pressure (190, 210 and 230 bar) fueled with FOME (B20). The test results show that the optimum fuel injection pressure is 210bar with FOME. At this optimized pressure the thermal efficiency is similar to diesel with reduction in carbon monoxide, unburned hydrocarbon and smoke emissions with an increase in oxides of nitrogen was observed compared to diesel. It is concluded that fish oil biodiesel at 210bar injection pressure is more efficient than at 190bar and 230bar, except for oxides of nitrogen emissions.**

Key words: Vegetable Oil, Fish oil methyl ester, Injection Pressure, Performance and Emissions.

I. INTRODUCTION

To meet the growing energy needs resulting from spiraling demand and diminishing supply, alternative energy sources "mostly biofuels" are receiving more attention. In addition, the increasing global concern has caused to focus on the oxygenated diesel fuels because of the environmental pollution from internal combustion engines. These issues have triggered various research studies to replace petroleum based diesel fuel with the biofuels.

For diesel engines, a significant research effort has been directed towards using vegetable oils and their derivatives as fuels. Non-edible vegetable oils in their natural form called straight vegetable oils (SVO), methyl or ethyl esters known as treated vegetable oils, and esterified vegetable oils referred to as bio-diesel fall in the category of bio fuels. Bio-diesel is considered a promising alternative fuel for use in diesel engines, boilers and other combustion equipment. Compared to fossil diesel fuel, bio-diesel has several superior combustion characteristics. The fuel characteristics of bio-diesel are approximately the same as those of fossil diesel fuel and thus may be directly used as a fuel for diesel engines without any modification of the design or equipment. In addition, these are bio-degradable, can be mixed with diesel in any ratio and are free from sulphur.

Although bio-diesel has many advantages over diesel fuel, there are several problems that need to be addressed such as its lower calorific value, higher flash point, higher viscosity, poor cold flow properties, poor oxidative stability and sometimes its comparatively higher emission of nitrogen oxides [1]. Bio-diesel obtained from some feed stocks might produce slightly more oxides of nitrogen (1–6%), which is an ozone depressor, than that of fossil origin fuels but can be managed with the utilization of blended fuel of bio-diesel and high speed diesel fuel [2]. It is found that the lower concentrations of bio-diesel blends improve the thermal efficiency. Reduction in emission and brake specific fuel consumption is also observed while using B10 [3].

The performance and emission characteristics of diesel engines depends on various factors like fuel quantity injected, fuel injection timing, fuel injection pressure, shape of combustion chamber, position and size of injection nozzle hole, fuel spray pattern, air swirl etc. The fuel injection system in a direct injection diesel engine is to achieve a high degree of atomization for better penetration of fuel in order to utilize the full air charge and to promote the evaporation in a very short time and to achieve higher combustion efficiency. The fuel injection pressure in a standard diesel engine is in the range of 200 to 1700 atmospheres depending on the engine size and type of combustion system employed.

1.1 Literature Review

Increased injector opening pressure has a significant effect on engine performance and emissions of diesel engines. An increase in injection pressure is found to enhance the atomization at the nozzle exit, resulting in a more distributed vapor, hence better mixing. The nozzle opening pressure was set by adjusting injector spring and valves were 170, 190,210 and 230 bar. The changes noted at maximum engine output were: 1. Brake thermal efficiency increases from 27.3% to 29.1%, 2. HC reduced from 166 to 130ppm, 3. NOx level increases with increasing IOP due to faster combustion and higher temperatures reached in the cycle and 4. Smoke level reduced from 4.6BSU to 3.2 BSU. Smoke levels steadily fall with increase in injector opening pressure due to improved mixture formation because of well-atomized spray [4, 8].

Power output & Brake thermal efficiency decreases with the increase in concentration of KME in diesel & increased with the increase in the injection pressure and fuel temperature. The brake specific fuel consumption and BSEC increased with the increase in the concentration of KME in diesel and decreased with the increase in injection pressure and fuel temperature. Exhaust gas temperature increase with the increase in concentration of KME in diesel, the increase in exhaust gas temperature was non significant with increase in fuel temperature and injection pressure [5].

Researchers at [6] investigated Pongamia Pinata Linn oil and diesel blend on the Single cylinder, direct injection diesel engine and tests were conducted for the entire load range (0 to 100% i.e., 0 to 5 hp) at constant speed of 1500 rpm and concluded that least CO and HC emissions were observed at 275 bar and 250 bar respectively and this is better than neat diesel fuel at standard injection pressure of 200 bar.

Rosli Abu Bakar, Semin and Abdul Rahim Ismail at [7] performed experiment on a diesel engine with four-cylinder, two-stroke, direct injection. Engine performance values such as indicated pressure, indicated horse power, shaft horse power, brake horse power, break mean effective pressure and fuel consumption have been investigated both of variation engine speeds - fixed load and fixed engine speed – variation loads by changing the fuel injection pressure from 180 to 220 bars. According to the results, the best performance of the pressure injection has been obtained at 220 bars, specific fuel consumption has been obtained at 200 bars for fixed load – variation speeds and at 180 bars for variation loads – fixed speed.

Increase in injection pressure improves the performance of the engine used in study with regard to the engine performance measured in terms of BSFC and BTHE. The highest performance is delivered by the engine at 250 bar injection pressure and compression ratio of 18 at which BSFC improves by 10% and BTHE improves by 8.9%. With regard to emission aspects, increase in compression ratio leads to increase in emission of HC and exhaust temperature whereas Smoke and CO emission reduces. NOx emissions are found to remain unaffected at higher injection pressure. The higher injection pressure helps in keeping the emissions of HC, NOx and Smoke at a lower level while increasing the CO and temperature of exhaust. For all combinations of compression ratio and injection pressure, the emissions of HC, NOx, smoke opacity and exhaust temperature are lower with pure bio-diesel against that of diesel fuel [8].

In this study, biodiesel produced from fish oil was used in a diesel engine. Variations in Performance and emission were investigated and effects of injection pressure on engine performance and exhaust emissions were studied. The tests were carried out on a single-cylinder diesel engine at three different injection pressures (190, 210 and 230 bar) at all load conditions. Results were compared to that of diesel performance.

2. EXPERIMENTAL PROCEDURE

2.1. Preparation of Fuel

Biodiesel from marine fish oil was produced in the laboratory scale set up consisting of reaction flask with condenser, digital rpm for controlling the magnetic stirrer. The volume of the glass reactor capacity was 2 liters, consisted of three necks, one for condenser and two for monitoring temperature and reactant inputs. A simple mercury thermometer is used to measure the reaction temperature.

The mixture of fish oil (100g), methanol (20:1 molar ratio with fish oil) and sulfuric acid (5% in vol. basis) was boiled in a reaction chamber fitted with a condenser at a temperature of 62–65 ^{o}C for 5 h. Then the top layer was separated and washed with alkali solution to reduce the pH to neutral and washed with salt water (5%) and dried in an oven for an hour to remove the traces of water. Finally the product obtained was fish oil methyl ester (FOME) which is called as biodiesel. The biodiesel fuel properties were tested as per the ASTM standard, given in Table 1. The important fuel property is viscosity, which plays a vital role in fuel atomization and penetration. It can be observed from the table that the viscosity of raw fish oil is high and after transesterification it reduces to nearly 1/7 times of raw oil. The reduction in viscosity enables the vegetable oil to be used as a fuel but still the viscosity is higher when compared to diesel. The heating value of raw oil is improved by transesterification process because of the presence of alcohol. The cetane number is almost same as that of diesel. The flash and fire point for methyl ester is higher compared to diesel, which is an advantage from the safety point of view.

Table1. Fuel properties of Diesel, Raw fish oil and fish oil biodiesel.

Sl. No.	**Properties**	**Diesel**	**Raw fish oil**	**Fish oil Biodiesel**
1	Density(kg/m^3)	850	913	882
2	Specific gravity	0.85	0.929	0.888
3	Kinematic viscosity at 40°C (Cst)	3.05	23.2	3.97
4	Calorific value(kJ/kg)	42800	43584.7	40877.68
5	Flash point(°C)	56	218	152
6	Fire point(°C)	63	236	160

2.2 Test Procedure

The tests were conducted at Heat Engine Laboratory of Mechanical Engineering Department, REVA ITM, Bangalore. The test equipment is seen in Fig.2.21. 4-stroke, 1-cylinder, constant speed, water cooled, direct-injection diesel engine was used. This engine was coupled to an eddy current dynamometer with a control system. The engine Specifications are shown in the Table 2. The injection pressure of the injector was varied by tightening or loosening the screw of the injector as shown in the Fig.2.22.Exhaust gas analysis was performed using a Five Gas Exhaust Analyzer with Probe. The gas analyzer is shown in Fig.2.23.

The experiments were conducted at no-load, 5n-m load, 10 n-m load, 15n-m load and 20n-m load condition with neat diesel operation. The tests were performed for both diesel and fish oil biodiesel (B20). The performance parameters such as BSFC, BSEC, BTE, EGT and emission characteristics like HC, CO, CO_2 and NO_X were evaluated and the results were compared with diesel performance.

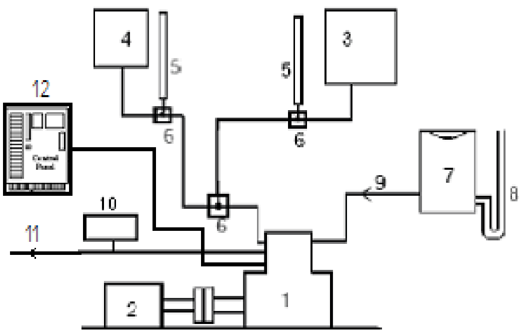

Fig. 2.21: Schematic layout of Experimental setup

1) Engine	7) Air Box
2) Dynamometer	8) Manometer
3) Fuel Tank (Bio-diesel)	9) Air flow direction
4) Diesel Tank	10) Exhaust Analyzer
5) Burettes	11) Exhaust flow
6) Three way valve	12) Control Panel

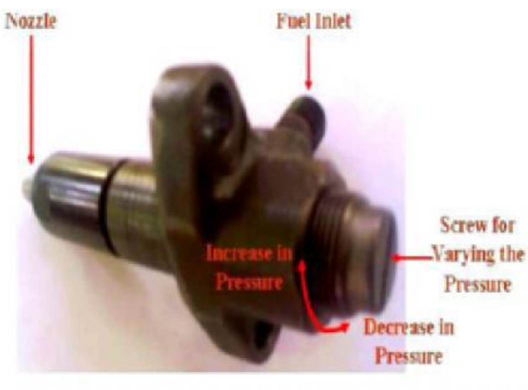

Fig. 2.22: Fuel Injector

Fig. 2.23: Five Gas Exhaust Analyzer (AVI) with Probe

3. RESULTS AND DISCUSSION

The tests were carried out on a diesel engine to investigate the variations in the engine performance and exhaust emissions for diesel and biodiesel fuels and to show the effects of fuel injection pressure. The results were compared for B20 FOME at injection opening pressures 190 bar, 210bar and 230bar with diesel.

Table 2 Engine Specifications

Model	**Kirloskar – AV1 Diesel Engine**
Engine Type	Single cylinder, Vertical, Direct Injection, Water Cooled
Bore/Stroke	80mm/110mm
Compression Ratio	16.5:1
Total Displacement Volume	0.553L
Specific Fuel consumption	245 g/KW-hr.
Speed	1500 rpm

3.1 Performance

As shown in Fig.3.11 it is observed that at all loads and injection opening pressures the fuel consumption is higher in case of FOME in compared with diesel which is due to higher density and lower heating value of FOME compared to diesel. Fig.3.12 shows the variation of energy consumption with load in which at all loads the energy consumption for FOME is higher than diesel. Fig.3.13 shows the brake thermal efficiency at different loads at different injection pressures. The results show that efficiency at full load is closer to diesel fuel because of improved atomization and better mixing process at higher injection pressures. It can be seen that at 230 bar injection pressure the efficiency is marginally higher than diesel. This may be due to the better combustion of FOME. The variation in Exhaust gas temperature with Brake power at different injection pressures is shown in the Fig. 3.14. It can be seen that the Exhaust gas temperature remains higher than diesel at all injection pressures.

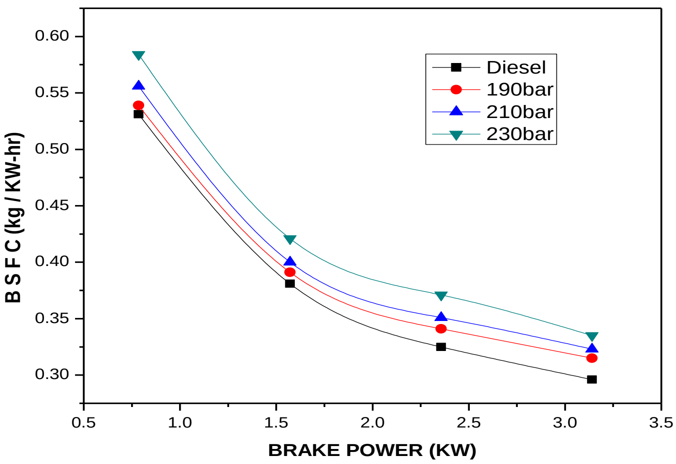

Fig. 3.11: Variation of BSFC with Brake Power

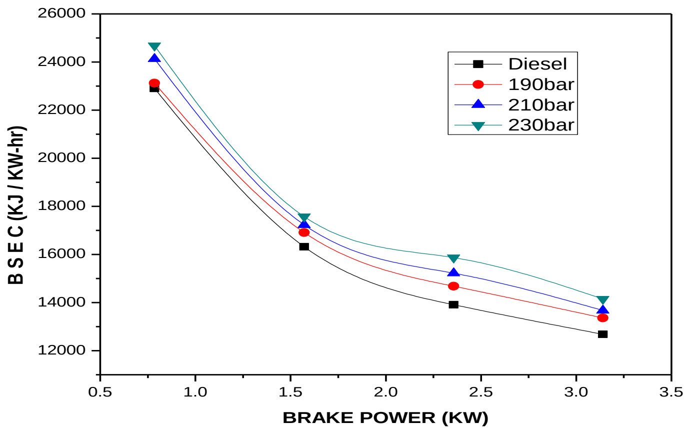

Fig. 3.12: Variation of BSEC with Brake Power

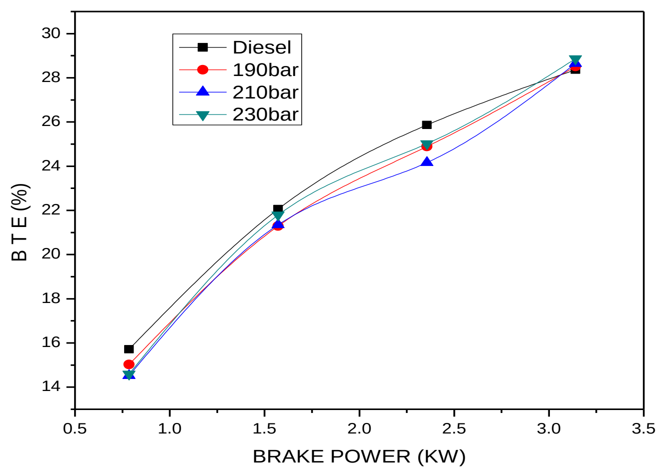

Fig. 3.13: Variation of BTE with Brake Power

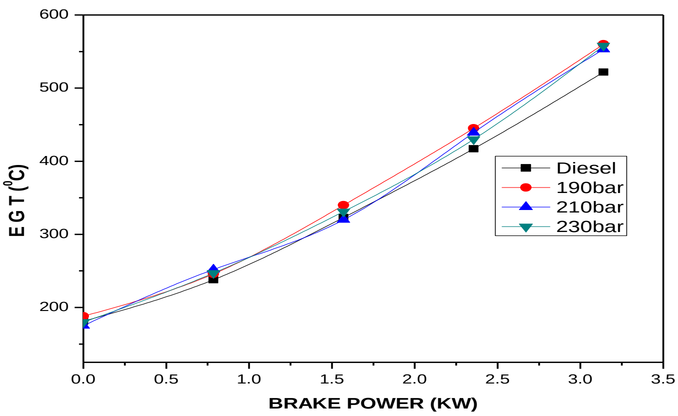

Fig. 3.14: Variation of EGT with Brake Power

3.2 Emissions

Fig.3.21 shows the variation of CO with brake power. It can be seen that at 190bar injection pressure the CO emissions are lower at all loads. Also at all injection pressures CO emissions for FOME are lower than that of diesel. This is because of better combustion with FOME. Fig.3.22 shoes the variation of CO_2 with brake power which indicates that with higher loads the CO_2 emissions increases at all injection pressures. As the injection pressure increases the fuel droplet travels with a high velocity and that may hit the wall of the combustion chamber, which may lead to higher unburnt hydrocarbon emissions. Fig.3.23 shows the variation of HC with injection pressure. It is clear from the figure that HC emissions at 230 bar injection pressure are higher than 190 and 210 bar injection pressure but still lesser than diesel fuel. As the heating value of FOME is low and has almost the same cetane number as diesel fuel and higher viscosity, the ignition delay will be more for FOME which in turn produce more oxides of nitrogen. But injecting the fuel at higher pressures partly solved this problem by making the physical process to take place faster and hence the production of oxides of nitrogen reduces as shown in Fig.3.24.

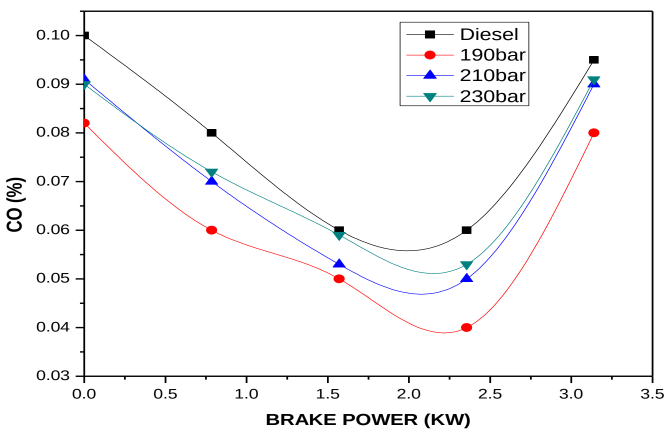

Fig. 3.21: Variation of CO with Brake Power

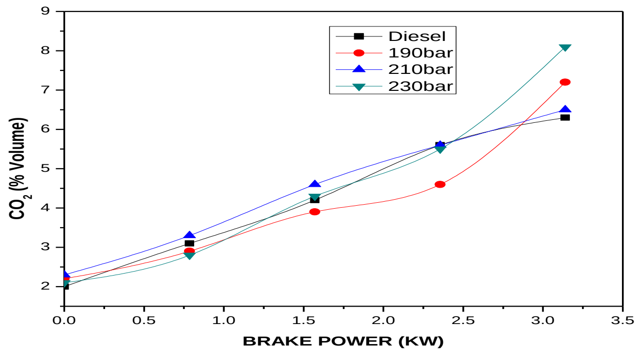

Fig. 3.22: Variation of CO_2 with Brake Power

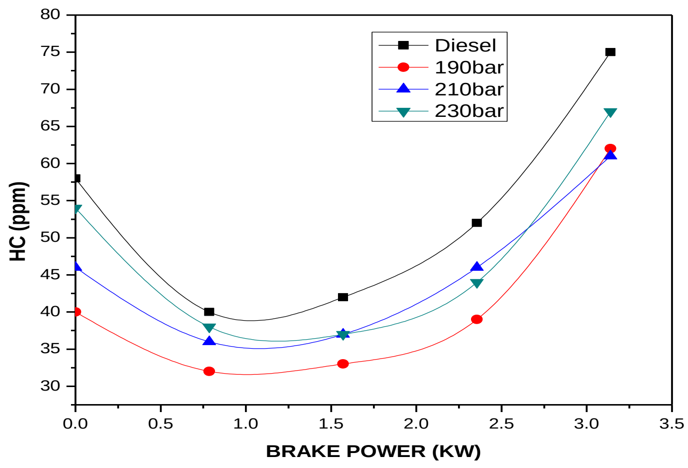

Fig. 3.23: Variation of HC with Brake Power

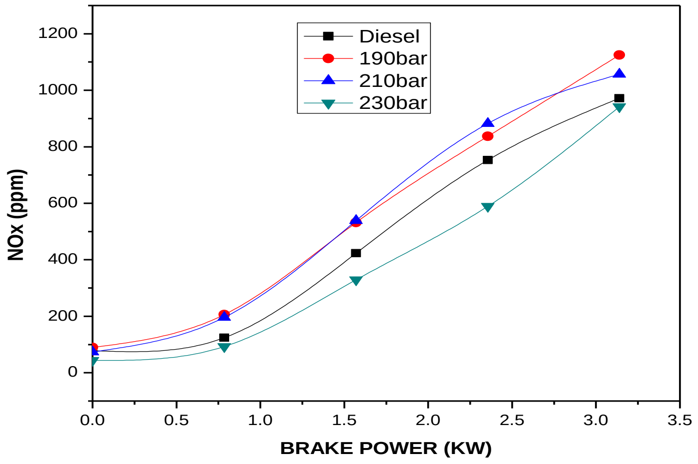

Fig. 3.24: Variation of NO_X with Brake Power

4. CONCLUSIONS

From the present experiment conducted at different injection pressures at all loads, the following conclusions are drawn.

- Because of low viscosity and low volatility neat fish oil is not suitable for diesel engine.
- By transesterification process fish oil properties can be brought closure to that of diesel.
- Being oxygenated fuel fish oil derived from animal fat, when used in a diesel engine reduces CO, HC and CO_2 emissions except NO_X at 190bar.
- At 230bar the thermal efficiency is improved with reduced emissions.

Finally it can be concluded that 210bar injection pressure may improve the performance and emissions with Fish oil methyl ester used in a diesel engine.

REFERENCES

[1] C.-Y. Lin, H.-A. Lin, *Diesel engine performance and emission characteristics of biodiesel produced by the peroxidation process*, Fuel 85 (2006) 298–305.
[2] F. Yohaness, *Fuelling a Small Capacity Agricultural Unmodified Diesel Engine with Macroemulsified Ethanol, Diesel and Jatropha Derived Biodiesel: Performance & Emission Studies*, M.E. Thesis, Mechanical Eng. Dept., Delhi College of Eng., Delhi, 2003.
[3] A.S. Ramadhas, C. Muraleedharan, S. Jayaraj, *Performance and emission evaluation of a diesel engine fueled with methyl esters of rubber seed oil*, Renewable Energy 30 (2005) 1789–1800.
[4] V.S. Hariharan1 and K. Vijayakumar Reddy, *Effect of injection pressure on diesel engine performance with Sea lemon oil*, Indian Journal of Science and Technology, Vol. 4 No. 8 (Aug 2011) ISSN: 0974- 6846.
[5] Y C BHATT and M K VERMA, *Effect of Fuel Temperature and Injection Pressure on Engine Performance with Karanja (Pongamia glabra) Methyl Ester Oil and Blends with Diesel.*
[6] B.K.Venkanna, Swati B, Wadawadagi & C.Venkataramana Reddy, *"Effect of Injection Pressure on Performance, Emission and Combustion Characteristics of Direct Injection Diesel Engine Running on Blends of Pongamia Pinnata Linn Oil (Honge oil) and Diesel Fuel"*, Agricultural Engineering international: The CIGR Ejournal. Manuscript number 1316. Vol. XI. , May, 2009.
[7] Rosli Abu Bakar, Semin and Abdul Rahim Ismail, *"Fuel Injection Pressure Effect on Performance of Direct Injection Diesel Engines Based on Experiment"*, American Journal of Applied Sciences 5 (3): 197-202, 2008 , ISSN 1546-9239.
[8] V.S. Hariharan and K. Vijayakumar Reddy, "Effect of injection pressure on diesel engine performance with Sea lemon oil", Indian Journal of Science and Technology Vol. 4 No. 8 (Aug 2011) ISSN: 0974- 6846.