Indian Journal of Science and Technology, *Vol 8(31), DOI: 10.17485/ijst/2015/v8i31/87321, November 2015*

ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Optimizing Spark Timing of Spark Ignited Ethanol Engine

M. V. N. Banu Gopan[1]* and K. Annamalai[2]

[1]Department of Mechanical Engineering, Bharath University, Chennai - 600073, Tamil Nadu, India; banugopan.mech@bharathuniv.ac.in

[2]Department of Automobile Engineering, MIT Campus, Anna University, Chennai - 600025, Tamil Nadu, India

Abstract

Alcohol is a good alternate fuel by comparing its performance, availability and renewability against fossil fuels. Ethanol is widely used in IC engines by blending small amount with petroleum fuels, but it is not solely used because its high boiling point and self-ignition temperature makes it difficult to burn in engines because, auto ignition also is not possible because of its high octane number and engine needs spark ignition. In order to overcome this problem we need a spark ignited engine with high compression ratio. So a high compression ratio engine is modified into spark ignited engine. A carburetor with 2mm main jet to supply excess fuel into engine is used in order to compensate its low calorific value. The engine used in this experiment was a single-cylinder direct injection diesel engine with a cylinder bore of 95mm, a stroke of 110 mm and a compression ratio of 13:1. The rated power was 5.3 kW at 1500 rpm. The engine has been tested at different loads for Ethanol against spark timings when piston is at TDC, 5 degree before TDC, 10 degree before TDC, 15 degree before TDC respectively. The optimum spark timing is found among the experimental basis for Ethanol.

Keywords: Ethanol Emissions, Neat Ethanol Engine

1. Introduction

It is apparent from the increasing popularity of light-duty diesel engines that alternative fuels, such as alcohols, must be applicable to diesel combustion if they are to contribute significantly as substitutes for petroleum-based fuels. Although replacing diesel fuel entirely by alcohols is difficult, an increased interest has emerged for the use of alcohols, and particularly lower alcohols (Methanol and Ethanol) with different amounts and different techniques in diesel engines as a dual fuel operation during recent years.

The increase in prices of petroleum based fuels, strict governmental regulations on exhaust emissions and future depletion of worldwide petroleum reserves encourage studies to search for alternative fuels. Ethanol is alternative fuel for diesel engines. It biomass – based renewable fuel, it offers reduction in life cycle CO_2 and it shows a significant PM reduction. Recently, the economics have also become much more favorable in the production of Ethanol and it is able to compete with the standard diesel fuels.

The studies on the use of Ethanol in Diesel engines can be divided into four. These are the Alcohol–Diesel fuel blend (mixture of the fuels prior to injection), Alcohol fumigation (the addition of alcohols to the intake air charge, Alcohol–Diesel fuel emulsion (using an emulsifier to mix the fuels to prevent separation) and dual injection (separate injection systems for each fuel).

As alternate fuels, ethyl and methyl alcohols stand out because of the feasibility of producing them in bulk from plentifully available raw materials. In the present work, Ethanol is used as the only fuel, in the engines by adopting spark plug assistance was used to initiate combustion.

The engine was tested for performance and emissions. The spark plug assisted Ethanol operation engine gave the highest brake thermal efficiency and the lowest emissions.

*Author for correspondence

2. Neat Ethanol Engine Setup

2.1 Requirements to Burn Ethanol in IC Engine

Engine needs spark plug setup to ignite Ethanol, because octane rating of Ethanol is high.

It's important to ensure proper air-fuel mixture admitting to the combustion chamber, so we can use a simple carburetor to facilitate proper air-fuel mixture[1].

If we want to use carburetor we need proper air correction system which will ensure proper vacuum pressure in the inlet manifold, so that fuel from carburetor sub-tank will be lifted up to air passage and mixes with air.

Engine needs proper temperature, that should be maintained inside the combustion chamber, because Ethanol fuel has high temperature of vaporization (78.9^{0}C), so that there is a possibility of condense of fuel inside the combustion chamber.

We can take a modified four stroke engine to our project, with compression ratio 13:1, in order to maintain high temperature[2]. So that fuel will be in proper mixture to facilitate easy catching of fire.

2.2 Engine Selection

While converting CI engine as SI engine, we need to go for two big modifications.

- Modification required for spark ignition circuit.
- Modification required for admitting fuel into the engine.

2.2.1 Modification Required for Spark Ignition Circuit

A simple battery ignition system circuit is used here,

There is,

- 12V battery.
- High tension 12V ignition coil.
- High tension cables.
- Spark plug.
- A contact breaker point with condenser.

The problem here is, in the selected engine there is no provision for fixing contact breaker point and spark plug. So it requires some modification in the system to make those provisions[3].

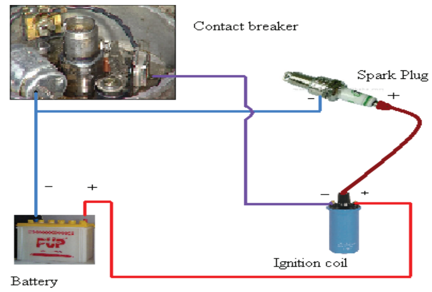

Figure 1. Battery ignition system.

2.2.1.1 Modification in Cylinder Head

The selected engine freed injector hole is modified to fix spark plug.

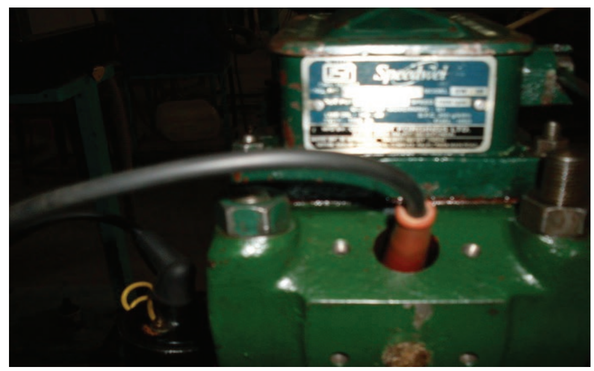

Figure 2. Cylinder head with spark plug.

There is injector hole of 8.5mm diameter in the cylinder head. Tap is made using 10mm tap tool. This inner thread is perfectly suitable for spark plug and is fitted.

2.2.1.2 Modification in Cam Shaft

In the usual cam shaft there is ball spring for governor operation[5]. Engine needs some cam arrangement that should break contact breaker point, so that high voltage charge will be supplied to spark plug to produce high intensity spark, in order to ignite fuel easily.

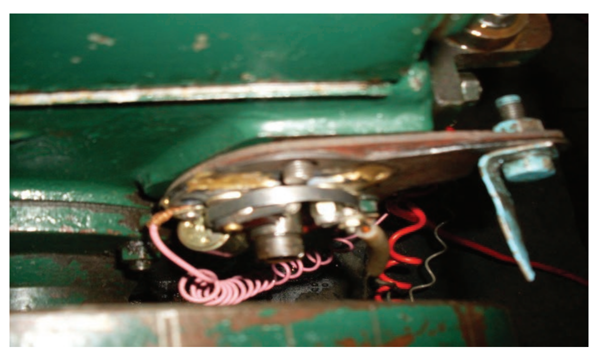

Figure 3. External ignition cam and contact breaker.

After removing governor ball spring arrangement there will be a through hole in the camshaft at the center. This hole is bored to 8.5mm and 10mm coarse tap is made inside to fix a single point cam which will be projecting outside crank case and flywheel[4]. Here in the outer periphery of this cam will be surrounded by a contact breaker point setup and connections are made and circuit has been checked as shown in Figure 3.

2.2.1.3 Tuning and Adjusting of Spark Timing

In general spark will be given at the end of compression stroke, so that fuel will be ignited and will be burnt. Strokes can be found by watching the movement of the rocker arm by rotating flywheel. Here at the end of compression stroke, there is TDC, and TDC marking in the flywheel is shown by a pointer. When pointer is at TDC marking ignition cam has been tilted so as to open contact breaker point. This ensures spark exactly by tilting the ignition cam so as to open contact breaker point.

2.2.2 Modification Required for Admitting Fuel into the Engine

A simple BULLET (MIKECARB) carburetor is fixed at the inlet manifold of the engine.

As Ethanol's calorific value (29800Kj/kg) is much lower[6]. We need to give more amount of Ethanol fuel into the engine so that power will be better. Here we used 1.5mm diameter and 2mm diameter main jets, finally 2mm diameter jet gave better operation and it is taken for the experiment.

3. Experimental Setup and Procedure

3.1 Experimental Setup

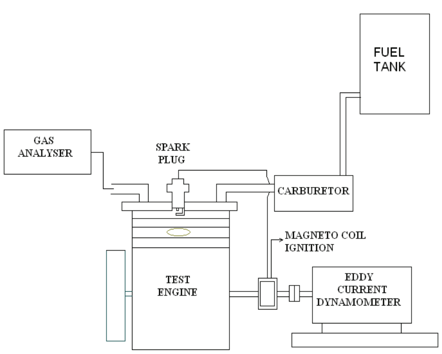

Figure 4. Experimental set up for neat ethanol fuel.

3.2 Experimental Procedure

Engine modifications were checked. Fuel tube is connected to the carburetor at the inlet manifold and the other end is connected to the burette[7]. Fuel is filled in the burette. A 12V battery is connected to the spark circuit. Positive pole is connected to the high tension ignition coil and negative pole is grounded on the engine. Spark timing is checked by rotating flywheel of the engine as per procedure and the right spark timing is ensured.

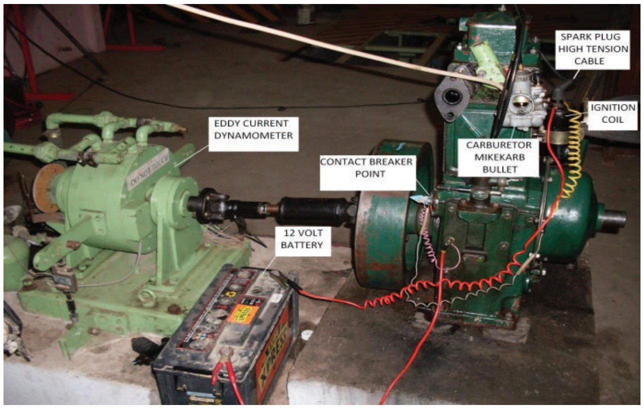

Figure 5. Modified engine.

The engine is started by adjusting the air correction valve to correct position, Then engine is started and allowed to warm up for 30 minutes. Speed of the engine can be varied by pulling throttle valve cable.

Readings are taken for without loading condition, and load is applied gradually through an eddy current dynamometer. For every load change there will be a drop in speed, because the engine is throttle controlled one. This speed change can be brought back to original speed by adjusting throttle to the right amount and readings were taken.

Time taken for 10cc of fuel consumption is noted. The sensor probe is inserted into the exhaust pipe and the other end is connected to the emission analyzer. The load is varied from no load condition (0 to 18NM). For every load change speed is brought back and the engine is allowed to run for 2 minutes and then the readings are taken. The amount of emissions for each load is noted down from the analyzer[8].

4. Results and Discussion

Performance characteristics and various emission characteristics of four different spark timings has been taken and plotted as graph. Four different spark timings are when piston is at Top Dead Center, 5 Degree before Top Dead Center, 10 Degree before Top Dead Center and 15 Degree before Top Dead Center[9].

4.1 Performance Charecteristics

Performance characteristics Fuel consumption, brake specific energy consumption, thermal efficiency, for four different spark timings with different loading conditions were calculated and plotted as graph. Among them, optimized spark timing is compared.

4.1.1 Perfomance Characteristics of Ethanol for Different Spark Timing

4.1.1.1 Fuel Consumption

Fuel consumption is an important criterion, because it's directly related with economy of the country and availability of the fuel for the future use. Fuel consumption is usually calculated as Total Fuel Consumption (TFC).

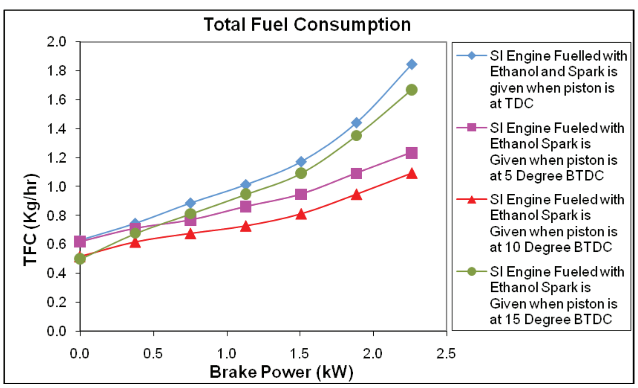

Figure 6. Fuel consumption with respect to brake power.

Here total fuel consumption is number of kilogram of fuel consumed per hour of running, this is increasing with respect to load. 10 degree BTDC spark taming gives minimum fuel consumption comparing to all the other spark timings. 5 degree before TDC also gives comparable results with 10 degree spark timing[10].

4.1.1.2 Brake Thermal Efficiency

Brake thermal efficiency shows the performance of the engine for the particular fuel. It actually means the utilization capability of the engine to convert all the chemical energy into heat and to recover all the heat, without wasting it to surroundings.

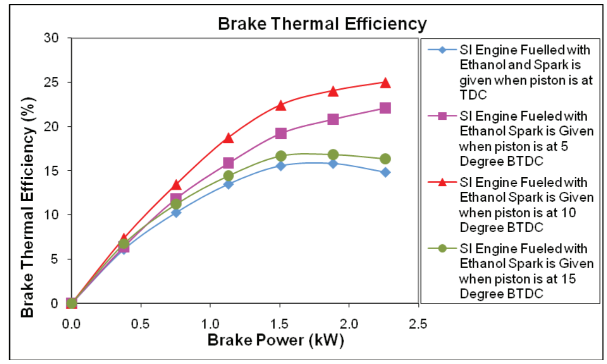

Figure 7. Brake thermal efficiency with respect to brake power.

Figure 7 shows, thermal efficiency of the 10 degree BTDC spark timing is high due to better utilization of combustion energy of the fuel compared to all the other spark timings. This 10 degree timing is utilized for the initial starting of the combustion, and after piston reaching top dead center it gives intensive combustion, and consumes all the energy of the fuel entering inside the engine so that this timing is better compared to all the other timings.

4.1.1.3 Energy Consumption

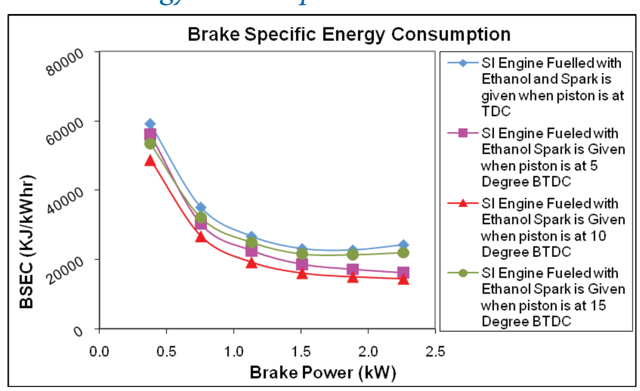

Figure 8. Specific energy consumption with respect to brake power.

Figure 8 shows the energy consumption by the engine is reducing with respect to rise in engine load. Energy consumption is very high for low loads initially and then it's reducing for higher loads. 10 degree BTDC spark timing shows better utilization of combustion energy, so that its energy intake is low compared to other spark timings. Spark timing at TDC shows high energy consumption; because fuel starts its initial ignition at TDC, and it will have intense combustion 15 to 20 degree after ignition starts so that more un-burnt mixture escapes from the zone. This increases more fuel intake and hence more energy consumption.

4.2 Emission Characteristics

Exhaust emission characteristics of the engine for various spark timings and for various loads were analyzed using a CRYPTON Exhaust Gas Analyzer. Here there is a probe inserted in to the exhaust pipe of the Engine.

Various exhaust emissions hydro carbon this shows improper burning of the fuel, NO_x-Oxides of Nitrogen, emission occurs when engine is running at high temperature and when availability of oxygen is plenty, CO-Carbon-monoxide emission shows incomplete combustion, CO_2-Carbon-di-Oxide, generally it is not been considered as a pollutant because higher emission of CO_2 ensures complete combustion. As like all other emissions CO_2 also measured by the analyzer and results are plotted as graph. Finally O_2 this shows availability of oxygen in the combustion zone.

4.2.1 Oxides of Nitrogen

Figure 9 shows the variation in NO_x emission with respect spark timing of Ethanol and diesel operation. Here NO_x emission is increasing up to 60PPM for optimized spark timing of 10 degree BTDC. NO_x increase 30% for 10degree BTDC spark timing and decreases about 15% for spark given when piston is at TDC.

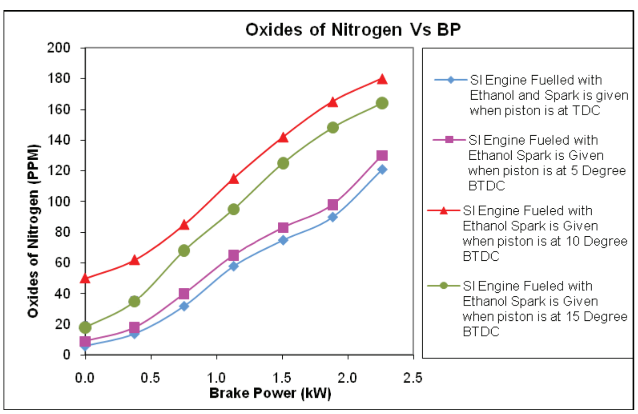

Figure 9. NO_X emission with respect to brake power.

4.2.2 Carbon Monoxide Emission

Carbon monoxide emission is potentially dangerous; it should be reduced for the fuels having oxygen content in it, as a good sign carbon-monoxide is reducing as the rise in brake power. But here, Ethanol has twice the time high CO emission compared to diesel in low loads and becomes low when load increases.

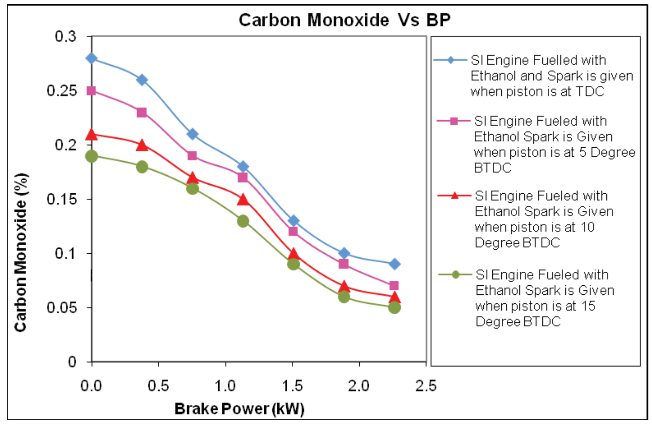

Figure 10. CO emission with respect to brake power.

4.2.3 Carbon-di-Oxide Emission

Figure 11 shows the carbon-di-oxide emission increasing as the brake power of the engine rises. So we can compare with the previous graph carbon-monoxide reducing as increase in brake power because whenever we increase the load on the engine it will supply large quantity of the fuel. So temperature of the engine will get increased so that combustion will be somewhat good and all the carbon-monoxide will become CO_2.

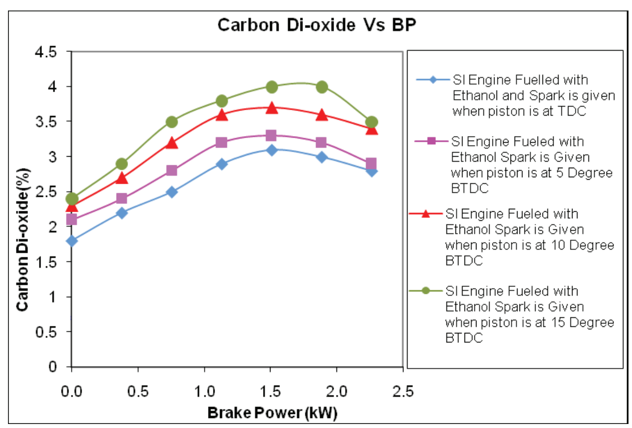

Figure 11. CO_2 emission with respect to brake power.

4.2.4 Hydro Carbon Emission

Figure 12 shows; hydro carbon emission is reducing with respect to increase in load. As load of the engine increases, more amount of fuel will be taken into the engine to compensate the increase in load this increases temperature inside the engine, so that there is a possibility of complete

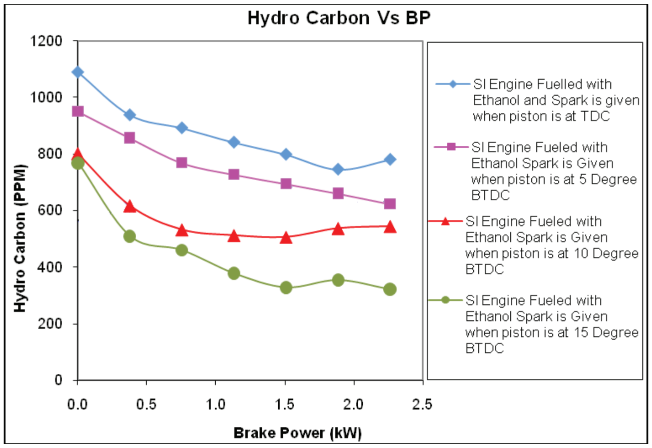

Figure 12. HC emission with respect to brake power.

combustion so that hydro carbon emission reduces as increase in load.

4.2.5 Oxygen in Exhaust Emission

Figure 13 shows the percentage by volume of oxygen coming out with exhaust gases as the increase in brake power for various spark timing. It measures the amount of oxygen has not participated in the combustion. In high loading conditions escape of oxygen is hardly possible because high temperature during that period makes them to react with HC as well as with nitrogen.

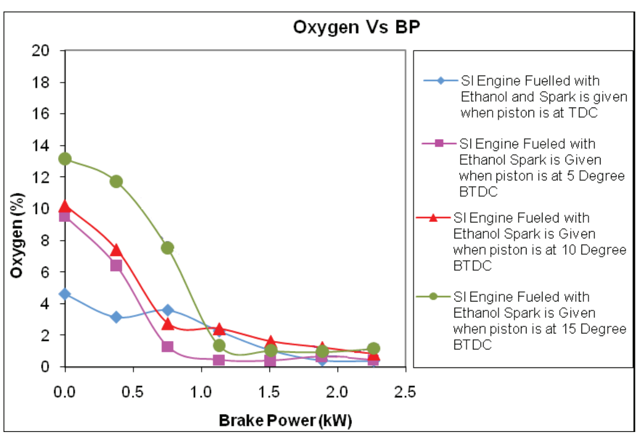

Figure 13. O_2 emission with respect to brake power.

5. Conclusion

Performance and emissions characteristics tested on the modified engine fuelled with neat Ethanol for various spark timings shows that,

Fuel consumption is higher because of its less colorific value. But in price vice cost of operation is less.

Thermal efficiency is better for the optimized spark timing when spark is at 10 degree Before Top Dead Center (BTDC).

On discussing emission characteristics hydro carbon emissions is lesser compared to optimized spark timing which is much lower for the spark timing of 15 degree BTDC.

NO_x emission is higher for optimized spark timing when spark is at 10 degree BTDC, because this particular spark timing gives better fuel consumption and complete combustion, so there is an increase in temperature of the zone increases reaction of nitrogen with excess oxygen which is available in plenty as fuel itself has oxygen content.

For improvement in performance of the Ethanol operated engine, small amount of rise in NO_x emission can be compromised.

6. References

1. West BH, Lopez AJ, Theiss TJ, Graves RL, Storey JM, Lewis SA. Fuel economy and emissions of the ethanol-optimized saab 9-5 biopower. SAE Transactions. 2007. p. 1–12.
2. Kumaravel A, Meetei ON. An application of non-uniform cellular automata for efficient cryptography. IEEE Conference on Information and Communication Technologies. 2013. p. 1200–5. ISSN: 1681-8016.
3. Brusstar M, Stuhldreher M, Swain D, Pidgeon W, et al. High efficiency and low emissions from a port-injected engine with neat alcohol fuels. U. S. Environmental Protection Agency; 2002.
4. Kumar SS, Karrunakaran CM, Rao MRK, Balasubramanian MP. Inhibitory effects of Indigofera aspalathoides on 20-methylcholanthrene- induced chemical carcinogenesis in rats. Journal of Carcinogenesis. 2011; 10(1). ISSN: 1477-3163.
5. Wrage KE, Goering CE. Technical feasibility of diesohol. Agricultural Engineering. 1979; 60(10):34.
6. Ramaswamy S, Sengottuvelu S, Haja Sherief SH, Jaikumar S, Saravanan R, Prasadkumar C, Sivakumar T. Gastroprotective activity of ethanolic extract of Trachyspermum ammi fruit. International Journal of Pharma and Bio Sciences. 2010; 1(1). ISSN: 0975-6299.
7. Mohammadi A, Kakuta TIT, Ka S-S, et al. Fuel injection strategy for clean diesel engine using ethanol blended diesel fuel; 2005. p. 1–11.
8. Subhashree AR, Parameaswari PJ, Shanthi B, Revathy C, Parijatham BO. The reference intervals for the haematological parameters in healthy adult population of Chennai, Southern India. Journal of Clinical and Diagnostic Research. 2012; 6(10):1675–80. ISSN: 0973-709X.

9. Ganesan V. Internal Combustion Engines. Tata McGraw-Hill Education; 2004.
10. Sankari SL, Masthan KMK, Babu NA, Bhattacharjee T, Elumalai M. Apoptosis in cancer- An update. Asian Pacific Journal of Cancer Prevention. 2012; 13(10):4873–8. ISSN: 1513-7368.
11. Kimio T, Natarajan G, Hideki A, Taichi K, Nanao K. Higher involvement of subtelomere regions for chromosome rearrangements in leukemia and lymphoma and in irradiated leukemic cell line. Indian Journal of Science and Technology. 2012 Apr; 5 (1):1801–11.
12. Cunningham CH. A Laboratory Guide in Virology. 6th ed. Minnesota: Burgess Publication Company; 1973.
13. Sathish Kumar E, Varatharajan M. Microbiology of Indian Desert. In: Sen DN, editor. Ecology and Vegetation of Indian Desert. India: Agro Botanical Publication; 1990. p. 83–105.
14. Varatharajan M, Rao BS, Anjaria KB, Unny VKP, Thyagarajan S. Radiotoxicity of Sulfur-35. Proceedings of 10th NSRP; India. 1993. 257–8.
15. 01 Jan 2015. Available from: http://www.indjst.org/index.php/vision