ISSN:0975-3583,0976-2833 VOL7,ISSUE04, 2016

Characterization of temperature and combustion charged Homogeneous Charge

R. Mohan kumar[1]and V R Vidhun[2]B.Manoharan[3] and M. Jeganathan[4]

[1&2]Department of mechanical Engineering , Nehru Institute of Technology,

Kaliyapuram, Coimbatore 641105, Tamilnadu, India

[3]Professor (Tenure), PMIST, Vallam, Thanjavur.

[4]Associate Professor, Designed Environment and Research Institute (DEAR Institute) Trichy- 621 213.

rmk.gvr@gmail.comjegann1978@gmail.com

Abstract

The experimental investigations have been conducted with different inlet charge temperatures of 90^0 C, 100^0 C, 110^0 C, 120^0 C, 130^0 C, 140^0 C and limited the charge temperature for poor output and higher level of emissions of HCCI engine. It describes the result of ultra low NOx and soot emissions in biodiesel fuelled HCCI engine compared to diesel engine. The NOx and soot emissions are reduced about 40% and 28% respectively than convention diesel engine. The HCCI engine has consumes lower amount of fuel and produced higher power output at high load operation. And the result shows, the brake thermal efficiency (BTE) has been increased with increasing the charge temperature. The inlet charge temperature reflects, HC and CO emissions are reduced in HC and CO emissions in biodiesel fuelled engine.

Keywords: Engine, biodiesel, emission, efficiency, temperature

1. Introduction

Biodiesel is suitable alternative renewable fuel for diesel engines. Biodiesel is produced from renewable resource like vegetable oil or animal fat and it is biodegradable. It can be used as neat or blended with diesel in compression ignition engines. The high oxygen molecule and the lower calorific value of biodiesel generally results in a measured loss of engine power and increase of fuel consumption but the engine efficiency is unaffected or even improved (1-4). Regarding exhaust emissions, the use of biodiesel results in lower emissions of unburned hydrocarbons, Carbon monoxides, smoke and particulate matter (PM). The majority of the published work indicates some increase in NOx emissions with biodiesel compared to standard diesel fuel (5-7).

Due to the high NOx and lower brake thermal efficiency of biodiesel used compression ignition diesel engine, a homogeneous charged compression ignition engines are try to use with biodiesel. The HCCI engines are being actively developed because they have the potential to highly efficient and to produce low emissions. The HCCI engine can have the efficiency closer to the conventional diesel engine, with low levels of emissions of NOx and PM. This occurs because the combustion develops with low temperature and burns a premixed air/fuel mixture. On the other hand, CO and HC emissions increased due to low temperature combustion process of HCCI engine (8-10).

In reference (11) author used diesel and rapeseed methyl ester in HCCI engine was controlled by exhaust gas re-circulation. The NOx emission was decreased but smoke emission considerably increased due to the recirculation of burnt gas into the combustion chamber. The rate of heat release by the engine is decreased by the EGR and it favour for NOx emission reduction, but it increased the rate of smoke emission. Junjum Ma et al. (2008) investigated duel fuelled HCCI engine with different premixed ratio using diesel as a primary fuel and n- heptane used secondary fuel. Where diesel fuel was injected in in-cylinder and n-heptane was used to inject the fuel in engine inlet port. The author found that NOx emissions were decreased at lower pre mixed ratios and increased at higher pre mixed ratios. The variations of fuel premixed ratios could not affect the soot formation. From the result, it was identified that the formation CO emissions were depends on rate of combustion. The CO emissions were increased with higher pre mixed ratios (12). Moteza Faith et al. (13) analysed the influence of exhaust gas recirculation on HCCI engine combustion and emissions using n-heptane / natural gas as a fuel. The exhaust gas recirculation was used to control the combustion process and investigated the possibility of controlling the combustion phase and combustion duration.

John abrahim et al. (14) studied combustion characteristics of HCCI engine using n-heptane, methyl decanote and dimethyl ether. Ignition delay and NOx formation rates of three different fuel was investigated. The ignition delay of methyl decanote was shorter than dimethyl ether for all oxygen concentration. In general ignition delay was depends on O_2 concentration in the air-fuel charge. The ignition delay of DME is even shorter than that of methyl decanote addition of NO to simulate EGR effects reduced the ignition delay and NOx emission. Similarly Lu Xingcai et al. used ethanol and n-heptane fuel in HCCI engine, the author conducted the experimental investigation in single cylinder engine with using neat fuel and blend of 10%, 20%, 30%, 40% and 50%. He resulted that the HC emissions for n-heptane and blends of 10-30% fuels have very low, while HC emission has been increased for 40%and 50% of ethanol and n-heptane blends. Because of the blends were gradually increased the ignition delay (15).

Mingfa Yao et al. (16) analysed controlling strategies of dimethyl ether and methanol fuelled HCCI engine, the exhaust gas recirculation was used to control combustion process. The ignition delay and combustion duration could be regulated by the DME percentage and EGR rates. The rate of HC emissions were depends on DME percentages. The author concluded that for normal combustion, adopting larger DME percentage and EGR rates. This paper investigated the performance and emission characteristics of HCCI engine fuelled with cotton seed methyl ester. In this study, the HCCI combustion was controlled by varying the inlet charge temperature with certain limits by 90^0 C-140^0 C. And also analysed the effect of charge temperature on HCCI combustion phase parameters like as start of combustion (SOC) and combustion duration. The variations in combustion phase could impact on HCCI engine performance and emissions were also studied. (Vasanthy and Jeganathan 2007, Vasanthy et.al., 2008, Raajasubramanian et.al., 2011, Jeganathan et.al., 2012, 2014 , Sridhar et.al., 2012, Gunaselvi et.al., 2014, Premalatha et.al., 2015, Seshadri et.al., 2015, Shakila et.al., 2015, Ashok et.al., 2016, Satheesh Kumar et.al., 2016).

2. Methodology

Experimental setup

A single cylinder, four stroke, water cooled, DI diesel engine was used in this research work. And it was slightly modified as port fuel injected HCCI engine with DI injection system. The specifications of the modified kirloskar SV1 engine is listed in table 1. Figure 1 show the experiment set up of HCCI mode engine. In HCCI engine the homogeneous air-fuel mixture is created by electronic controlled fuel injector on intake manifold controlled by ECU. The electrical heater is connected with engine suction pipe and it the temperature is controlled by ECU. In this port fuel injection the fuel is injected on intake air stream during the suction stroke. The fuel injection timing is controlled by the electronic controlled unit.

ISSN:0975-3583,0976-2833 VOL7,ISSUE04, 2016

One end of engine shaft is coupled with eddy current dynamometer for applying the load. The dynamometer is controlled by manually on control penal; it is placed separately near to the test engine and it is having a roller nab by using this to change the load on the engine. The applying load on the engine is shown in NM on digital meter. The test engine maintains the constant speed of 1800rpm for all loads condition. The speed of the engine shows in digital meter on control penal. Engine cooling water Inlet temperature and outlet water temperature are measured by thermo couple. And EGR with fresh charge temperature and engine exhaust gas temperature were measured by thermal sensor (T_2 and T_3). All temperature sensors are connected with control panel. These readings are displayed in digital meter on the control panel. AVL Di-gas analyser was used to measure the exhaust emission from the HCCI mode engine such as CO, HC, NOx, CO_2 and O_2.

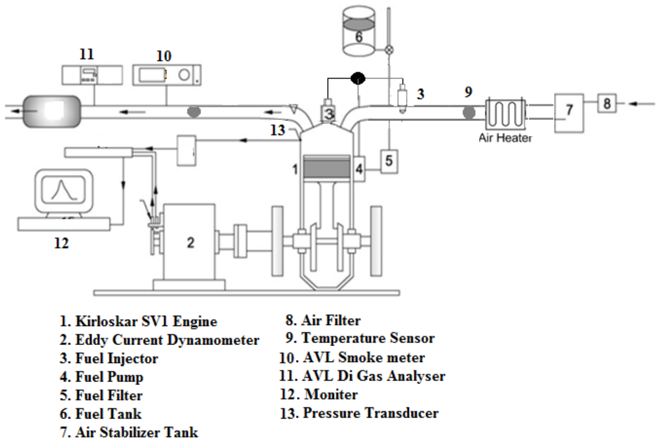

Figure.1 Experimental setup

Table.1

SL.N	Parameters	Specification
1.	Make and model	Kirloskar SV1
2.	General details	Single cylinder, four stroke, water cooled, port injection
3.	Bore	87.5 mm
4.	Stroke	110 mm
5.	Cubic capacity	0.661 lit
6.	Rated output	5.9 KW at 1800 rpm
7.	Compression ratio	17.5 : 1
8.	Inlet valve open BTDC	4.5 deg.
9.	Inlet valve close ABDC	35.5 deg.

10.	Exhaust valve open BBDC	35 deg.
11.	Port Fuel injection timing (BTDC)	10 deg.
12.	Direct fuel injection Timing(ATDC)	10 deg

Engine Specifications

3. Experimental Procedure

Table.3

Properties of Cotton Seed Methyl Ester

PROPERTIES	CME
Density @ 15°C in gm/cc	0.8835
Specific gravity @ 15° /15°C	0.8848
Kinematic viscosity @ 40°C (mm^2/s)	6.83
Flash point (°C)	150
Fire Point (°C)	161
Cloud Point (°C)	27
Calorific value (kJ/kg)	40789
Cetane Number	52

Initially the engine has operated with no load condition, to achieve the saturated engine temperature. The experimental investigations have been carried with different inlet charge temperature such as 90^0 C, 100^0 C, 110^0 C, 120^0 C, 130^0 C and 140^0 C with constant engine speed of 1800rpm. The biodiesel has more viscosity and higher auto ignition temperature than reference diesel as listed in table 3. So The HCCI engine has initially started as DI mode engine that is biodiesel is directly injected on the combustion chamber and switch over the DI injector into port fuel injection. The electrical heater is used to control or increased the inlet charge temperature before inject the fuel. The fuel injection timing is totally controlled by ECU, depends on the load and engine speed can change the injection timing and injection duration. The speed sensor or optical sensor is adopted near the engine crank shaft used to identify the engine speed and position of piston inside the cylinder. The output of the sensor is feed to the ECU, depends on the signal the ECU can change the fuel injection time and injection duration.

4. Result and Discussion

The biodiesel has some advantages over diesel fuel like higher cetane number, no sulphur content and having 11% of oxygen molecules as shown in table 3. However biodiesel has some difficult properties such as high viscosity and lower calorific values are difficult the biodiesel used in HCCI engine. In general, biodiesel has consuming higher fuel with produced same level of power output than diesel engine. But the biodiesel fuelled engine has high level of NOx and Smoke. To overcome these limitations of biodiesel, which is try to use in HCCI mode engine, because HCCI engine has operated with lean air-fuel conditions with producing lower NOx and soot emissions.(Manikandan et.al., 2016, Sethuraman et.al., 2016, Senthil Thambi et.al., 2016).

4.2 Performance Characteristics

In fig.2 shows the variation specific fuel consumption with percentage of load on HCCI engine. In general HCCI engines have been consumed less amount of fuel than conventional DI diesel engine. The fig.2 indicates, biodiesel fuelled HCCI engine has much higher value of SFC compared to diesel fuelled HCCI engine due to lower calorific value of biodiesel. From the figure it also observed that the value of SFC is decreased with increase the charge temperature up to 130^0 C and get sudden increase for 140^0 C charge temperature. The reason behind this is due to high inlet air temperature; the inlet air molecules are extended and reduced the volumetric efficiency of air. So the power output of the engine is decreased, to compensate this issue the engine requires more fuels. The charge temperature of 130^0 C shows the lower SFC than other temperatures, higher viscosity of biodiesel has required more temperature to vaporise the fuel. In charge temperature of 130^0 C is vaporised the port injected biodiesel and form homogeneous charge before the compression process. So the fuel is complete combust and released high heat energy. The maximum reduction of SFC is about 12% at 60% of load on the engine.

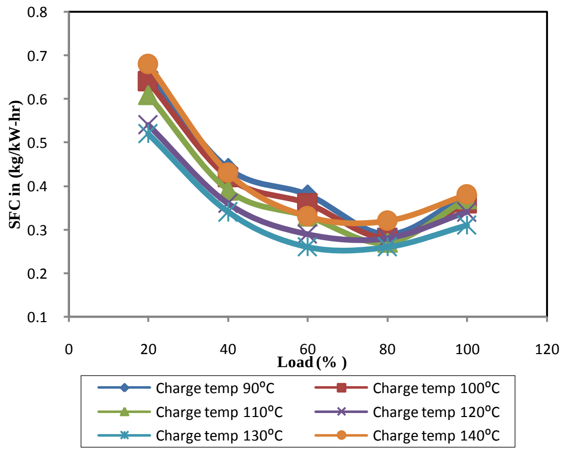

Figure.2 Variations in specific fuel consumption with percentage of load

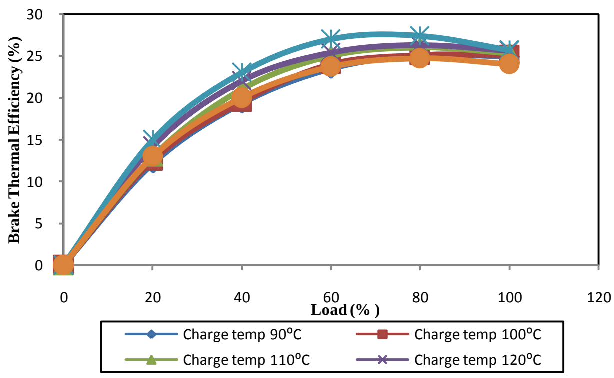

Figure.3 Variation of Brake thermal efficiency with percentage of load

The variation of brake thermal efficiency for HCCI engine operated with different load conditions are shown in figure3. The figure indicates the charge temperature of 130^0 C operated engine has lower BTE compared to other charge temperatures. The increase in BTE is about 12% at 60% of load. The brake thermal efficiency of HCCI engine is depends on percentage of fuel is converted to generate the heat energy. From the result it was observed that the increased in charge temperature could reduced the ignition delay and reduced the combustion duration.

4.3 Emissions Characteristics

The level of smoke emission in HCCI engine is based on percentage of complete combustion. The HCCI engine has lower smoke emission compared to conventional diesel engine due to lean charge operation of HCCI engine. The figure 3 shows the variation of smoke emissions with different load operation of HCCI engine. The diesel fuelled HCCI has produced low level of smoke emissions than biodiesel fuelled HCCI engine. In figure 3, the smoke emission of biodiesel fuelled engine have been increase with increase the charge temperature. The charge temperature of 120^0 C and 130^0 C shows the lower level of smoke emission. The maximum reduction of smoke is 25% than other HCCI engine operations. The temperature of 140C, operated HCCI engine has produced more smoke emission due to miss fire of the charge or due to high inlet charge temperature could reduced the volumetric efficiency of air, it leads to reduced the combustion efficiency and increased the smoke density.

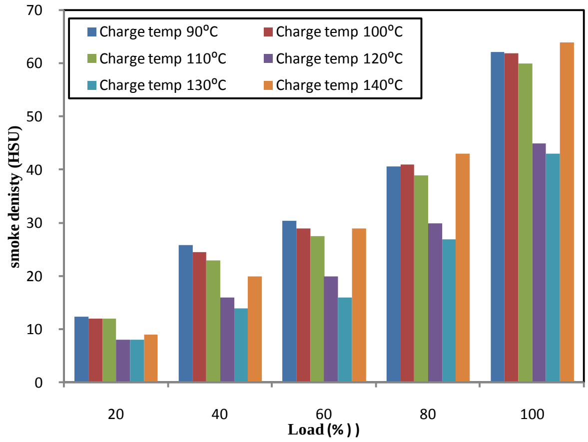

Figure.4 Variation in Smoke density with percentage of load

The figure 5 indicates the formation of NOx emissions with percentage of load on HCCI engine. The HCCI engine has produced very low NOx emission of 250-650 ppm compared to convention DI diesel engine. Because of HCCI engine has been operated lean air-fuel charge for all load operations. The figure shows, the level of NOx emissions increased with increase the charge temperature with increase the load percentages. The charge temperature of 140^0 C operated engine has minimum value of NOx emissions than other charge temperatures. The high charge temperature reduced the ignition delay and heat release rate from the charge. The charge temperature of 120^0 C and 130^0 C operated engine have higher NOx emissions than other temperatures.

The figure 6 and 7 shows the variation of CO and HC emissions of biodiesel fuelled HCCI engine. In general biodiesel fuelled HCCI engine has produced lower CO emissions compared to diesel fuelled HCCI engine. The reason is, the methyl ester has 11% more oxygen molecule and it favour for complete combustion. So CO molecules are converted as CO_2. From The figure 6, it was observed that, the level of CO emissions decreased with increase the charge temperature. The charge temperature of 130^0 C operated engine has low CO emission about .02 than other charge temperature. The figure 7 shows the charge temperature of 140^0 C operated HCCI engine has lower HC emissions compared to other charge temperatures.

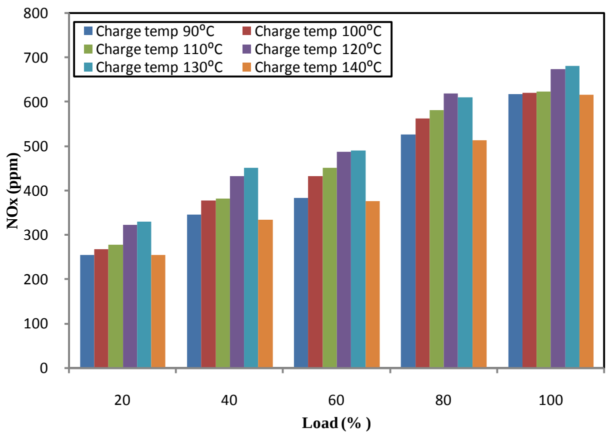

Figure.5 Variation of oxides of emission with percentage of load

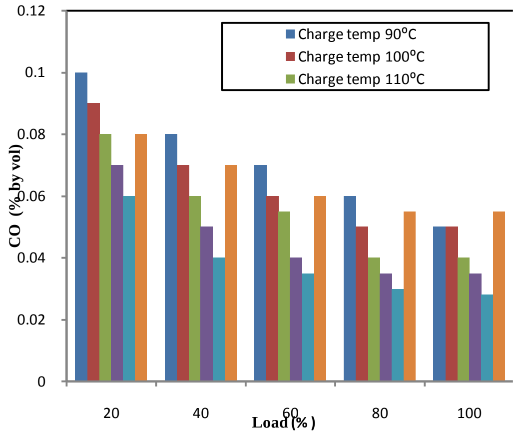

Figure.6 variation of CO emissions with percentage of load

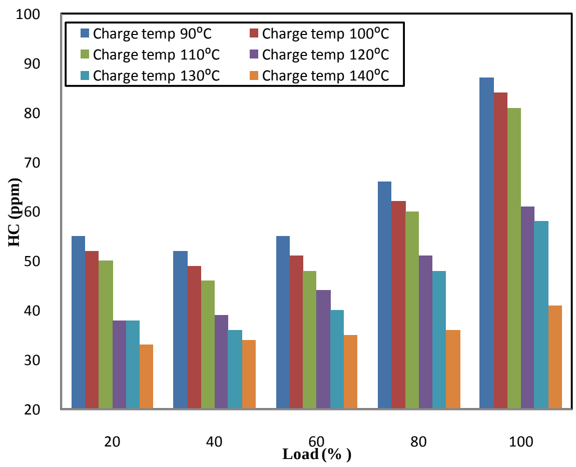

Figure.7 Variation of HC with different load

4.3 Combustion Characteristics

In figure 8, indicates the variation in start of combustion with increase the charge temperature of HCCI engine. From the figure it was observed that, the timing of start of combustion process is getting advanced with increase the charge temperature. The charge temperature of 130^0 C operated engine has early start of combustion process for all operated conditions. It shows,

ISSN:0975-3583,0976-2833 VOL7,ISSUE04, 2016

while increase the charge the start of combustion is get advance with increase the percentage of load.

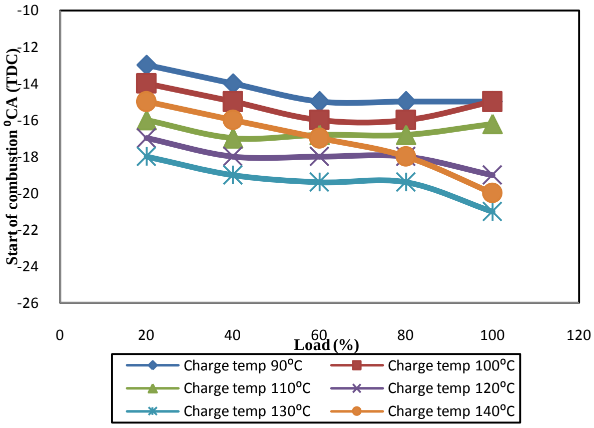

Figure.8 Variation in SOC with different load

Variation in combustion duration with different charge temperature of biodiesel fuelled HCCI engine shows in Figure 9. The combustion duration is decreased with increase the charge temperature. The charge temperature 130^0 C shows the minimum combustion duration compared to other temperatures. The combustion duration of the charge is depends on homogeneity of air-fuel mixture. If the mixture has high homogeneity, reduce the ignition delay and combustion duration.

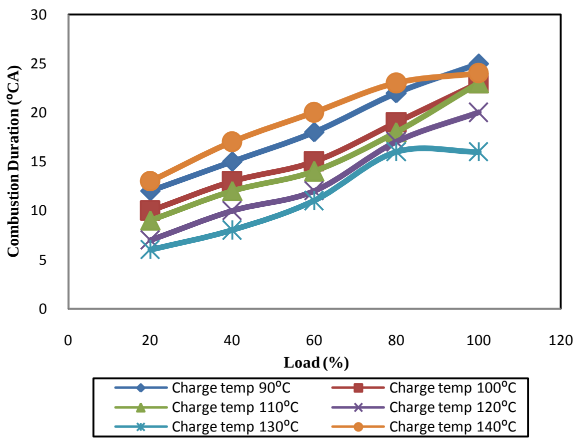

Figure.9 Variation of combustion duration with load

Conclusion

The specific fuel consumption of 130^0 C charge temperature operated HCCI engine has lower SFC compared to other charge temperatures. The level of SFC decreased with increase the percentage of load on the engine. The brake thermal efficiency of HCCI engine is increased with increase the charge temperature up to charge temperature of 90^0 C-130^0 C and then decreased with charge temperature of 140^0 C. The charge temperature of 130^0 C operated engine produced high BTE than other temperatures

The NOx and smoke emissions of biodiesel fuelled HCCI engine was very low compared to DI diesel engine. The level of NOx and smoke emissions were increased while biodiesel used in HCCI engine due to difference in ignition delay and combustion durations. The charge temperature of 140^0 C shows the minimum level of NOx emission and the charge temperature of 130^0 C operated

HCCI engine produced lower smoke emissions. The carbon monoxide and HC emission were much higher for HCCI engine than DI diesel engine. The biodiesel fuelled HCCI engine has lower CO emission due to higher oxygen molecule present in the cylinder during the combustion process. The level of CO and HC emission was decreased with increase the charge temperature. The combustion duration of the charge was decreased with increase the temperature.

Reference

[1] Czerwinski J. "Performance of HD-DI diesel engine with addition of ethanol and rapeseed oil. Transactions of Society of Automotive Engineering, 1994; 940545.

[2] Senthil Kumar M, Ramesh A, Nagalingam B. Use of hydrogen to enhance the performance of a vegetable oil fuelled compression ignition engine. International Journal of Hydrogen Energy 2003; 28(10):1143–54.

[3] Humke AL, Barsic NJ. "Performance and emission characteristics of a naturally aspirated diesel engine with vegetable oils (Part-2). Transactions of Society of Automotive Engineers 1981; 810955.

[4] Senthil Kumar M, Ramesh A, Nagalingam B. "An experimental comparison of methods to use methanol and Jatropha oil in a compression ignition engine". Biomass Bioenergy 2003;25(3):309–18.

[5] Muniyappa PR, Brammer SC, Noureddini H. "Improved conversion of plant oils and animal fats into biodiesel and co-product". Journal of Bioresoure Technology 1996; 56(1):19–24.

[6] Tashtoush GM, Al-Widyan MI, Al-Jarrah MM. "Experimental study on evaluation and optimization of conversion of waste animal fat into biodiesel". Journal of Energy Conversion Management 2004. In Press, Corrected Proof.

[7] Demirbas and S. Karslioglu, "Biodiesel production from vegetable oils and Animal Fat oil", Journal of energy sources, Part – A, 29:133-141, 2007.

[8] Yamasaki Y, Iida N. Numerical analysis of auto ignition and combustion of n-butane and air mixture in the homogeneous charge compression ignition engine by using elementary reactions. SAE paper 2003-01-1090; 2003.

[9] Lu Xingcai,Hou Yuchun,Zu Linlin,Huang Zhen. Experimental study on the auto-ignition and combustion characteristics in the homogeneous charge compression ignition(HCCI)combustion operation with ethanol/n-heptane blend fuels by port injection;2006:vol.5.p.2622–31.

[10] Christensen M, Hultqvist A, johansson B, Demonstrating the multi – fuel capacity of a homogeneous charge compression ignition engine with variable compression ratios. SAE 1999-01-3679;1999.

[11] Hatim Machrafi, Simeon Cavadias, Jacques Amouroux. A parametric study on the emissions from an HCCI alternative combustion engine resulting from the auto ignition of primary reference fuels. Applied Energy 85 (2008) 755-764.

[12] Junjum Ma, Xingcai Lu, Libin Ji, Zhen Huang. An experimental study of HCCI-DI combustion and emissions in a diesel engine with dual fuel. international journal of thermal science 47 (2008) 1235-1242.

[13] Morteza Faith, R Khoshbakhrti Saray, M David Checkel. The influence of exhaust gas recirculation (EGR) on combustion and emissions of n-heptane/ natural gas fuelled HCCI engine. Applied Energy (2011).

ISSN:0975-3583,0976-2833 VOL7,ISSUE04, 2016

[14] John Abraham, Seth R. Hoffman. A comparative study of n-heptane, methyl decanate, and dimethyl ether combustion characteristics under HCCI engine conditions. Fuel 88 (2009) 1199-1108.

[15] Lu Xingcai, Hou Yuchun, Zu Linlin, Huang zhen. Experimental study on the auto-ignition and combustion characteristics in the HCCI combustion operation with ethanol/ n-heptane blend fuels by port injection. fuel 85 (2006) 2622- 2631.

[16] Mingfa Yao, Zheng Chen, Zunqing Zheng, Bo Zhang, Yuan Xing. Study onthe controlling strategies of HCCI combustion with fuel of dimethyl ether and methanol. Fuel 85 (2006) 2046-2056.

[17] Vasanthy M and M. Jeganathan. 2007. Ambient air quality in terms of NOx in and around Ariyalur, Perambalur DT, Tamil Nadu. Jr. of Industrial pollution Control., 23(1):141-144.

[18] Vasanthy. M ,A.Geetha, M. Jeganathan,and A.Anitha. 2007. A study on drinking water quality in Ariyalur area. J.Nature Environment and Pollution Technology. 8(1):253-256.

[19] Ramanathan R ,M. Jeganathan, and T. Jeyakavitha. 2006. Impact of cement dust on azadirachtain dicaleaves – ameasure of air pollution in and Around Ariyalur. J. Industrial Pollution Control. 22 (2): 273-276.

[20] Vasanthy M and M. Jeganathan. 2007. Ambient air quality in terms of NOx in and around Ariyalur, Perambalur DT, Tamil Nadu. Pollution Research., 27(1):165-167.

[21] Vasanthy M and M. Jeganathan. 2008.Monitoring of air quality in terms of respirable particulate matter – A case study. Jr. of Industrial pollution Control.,24(1):53 - 55.

[22] Vasanthy M, A.Geetha, M. Jeganathan, and M. Buvaneswari. 2008. Phytoremediation of aqueous dye solution using blue devil (Eichhornia crassipes). J. Current Science. 9 (2): 903-906.

[23] Raajasubramanian D, P. Sundaramoorthy, L. Baskaran, K. Sankar Ganesh, AL.A. Chidambaram and M. Jeganathan. 2011. Effect of cement dust pollution on germination and growth of groundnut (*Arachis hypogaea* L.). IRMJ-Ecology. International Multidisciplinary Research Journal 2011, 1/1:25-30 : ISSN: 2231-6302: Available Online: http://irjs.info/.

[24] Raajasubramanian D, P. Sundaramoorthy, L. Baskaran, K. Sankar Ganesh, AL.A. Chidambaram and M. Jeganathan. 2011. Cement dust pollution on growth and yield attributes of groundnut. (*Arachis hypogaea* L.). IRMJ-Ecology. International Multidisciplinary Research Journal 2011, 1/1:31-36.ISSN: 2231-6302. Available Online: http://irjs.info/

[25] Jeganathan M, K. Sridhar and J.Abbas Mohaideen. 2012. Analysis of meterological conditions of Ariyalur and construction of wind roses for the period of 5 years from January 2002. J.Ecotoxicol.Environ.Monit., 22(4): 375-384.

[26] Sridhar K, J.Abbas Mohaideen M. Jeganathan and P Jayakumar. 2012. Monitoring of air quality in terms of respirable particulate matter at Ariyalur, Tamilnadu. J.Ecotoxicol.Environ.Monit., 22(5): 401-406.

[27] Jeganathan M, K Maharajan C Sivasubramaniyan and A Manisekar. 2014. Impact of cement dust pollution on floral morphology and chlorophyll of *healianthus annus* plant – a case study. J.Ecotoxicol.Environ.Monit., 24(1): 29-34.

[28] Jeganathan M, C Sivasubramaniyan A Manisekar and M Vasanthy. 2014. Determination of cement kiln exhaust on air quality of ariyalur in terms of suspended particulate matter – a case study. IJPBA. 5(3): 1235-1243. ISSN:0976-3333.

[29] Jeganathan M, S Gunaselvi K C Pazhani and M Vasanthy. 2014. Impact of cement dust pollution on floral morphology and chlorophyll of *healianthus annus.*plant a case study. IJPBA. 5(3): 1231-1234. ISSN:0976-3333.

[30] Gunaselvi S, K C Pazhani and M. Jeganathan. 2014. Energy conservation and environmental management on uncertainty reduction in pollution by combustion of swirl burners. J. Ecotoxicol. Environ.Monit., 24(1): 1-11.

[31] Jeganathan M, G Nageswari and M Vasanthy. 2014. A Survey of traditional medicinal plant of Ariyalur District in Tamilnadu. IJPBA. 5(3): 1244-1248. ISSN:0976-3333.

[32] Premalatha P, C. Sivasubramanian, P Satheeshkumar, M. Jeganathan and M. Balakumari.2015. Effect of cement dust pollution on certain physical and biochemical parameters of castor plant (*ricinus communis*). IAJMR.1(2): 181-185.ISSN: 2454-1370.

[33] Premalatha P, C. Sivasubramanian, P Satheeshkumar, M. Jeganathan and M. Balakumari.2015. Estimation of physico-chemical parameters on silver beach marine water of cuddalore district. Life Science Archives. 1(2): 196-199.ISSN: 2454-1354.

[34] Seshadri V, C. Sivasubramanian P. Satheeshkumar M. Jeganathan and Balakumari.2015. Comparative macronutrient, micronutrient and biochemical constituents analysis of *arachis hypogaea.* IAJMR.1(2): 186-190.ISSN: 2454-1370.

[35] Seshadri V, C. Sivasubramanian P. Satheeshkumar M. Jeganathan and Balakumari.2015. A detailed study on the effect of air pollution on certain physical and bio chemical parameters of *mangifera indica*plant.Life Science Archives. 1(2): 200-203.ISSN: 2454-1354.

[36] Shakila N, C. Sivasubramanian, P. Satheeshkumar, M. Jeganathan and Balakumari.2015. Effect of municipal sewage water on soil chemical composition- A executive summary. IAJMR.1(2): 191-195.ISSN: 2454-1370.

[37] Shakila N, C. Sivasubramanian, P. Satheeshkumar, M. Jeganathan and Balakumari.2015. Bacterial enumeration in surface and bottom waters of two different fresh water aquatic eco systems in Ariyalur, Tamillnadu. Life Science Archives. 1(2): 204-207.ISSN: 2454-1354.

[38] Ashok J, S. Senthamil kumar, P. Satheesh kumar and M. Jeganathan. 2016. Analysis of meteorological conditions of ariyalur district. Life Science Archives. 2(3): 579-585.ISSN: 2454-1354. DOI: 10.21276/lsa.2016.2.3.9.

[39] Ashok J, S. Senthamil Kumar, P. Satheesh Kumar and M. Jeganathan. 2016. Analysis of meteorological conditions of cuddalore district. IAJMR.2 (3): 603-608.ISSN: 2454-1370. DOI: 10.21276/iajmr.2016.2.3.3.

[40] Satheesh Kumar P, C. Sivasubramanian, M. Jeganathan and J. Ashok. 2016. South Indian vernacular architecture -A executive summary. IAJMR.2 (4): 655-661.ISSN: 2454-1370. DOI: 10.21276/iajmr.2016.2.3.3.

[41] Satheesh Kumar P, C. Sivasubramanian, M. Jeganathan and J. Ashok. 2016. Green buildings - A review. Life Science Archives. 2(3): 586-590.ISSN: 2454-1354. DOI: 10.21276/lsa.2016.2.3.9.

[42] Satheesh Kumar P, C. Sivasubramanian, M. Jeganathan and J. Ashok. 2016. Indoor outdoor green plantation in buildings - A case study. IAJMR.2 (3): 649-654.ISSN: 2454-1370. DOI: 10.21276/iajmr.2016.2.3.3.

[43] Manikandan R, M. Jeganathan, P. Satheesh Kumar and J. Ashok. 2016. Assessment of ground water quality in Cuddalore district, Tamilnadu, India. Life Science Archives. 2(4): 628-636.ISSN: 2454-1354. DOI: 10.21276/lsa.2016.2.3.9.

[44] Manikandan R, M. Jeganathan, P. Satheesh Kumar and J. Ashok. 2016. A study on water quality assessment of Ariyalur district, Tamilnadu, India. IAJMR.2 (4): 687-692.ISSN: 2454-1370. DOI: 10.21276/iajmr.2016.2.3.3.

[45] Sethuraman G, M. Jeganathan, P. Satheesh Kumar and J. Ashok. 2016. Assessment of air quality in Ariyalur, Tamilnadu, India. Life Science Archives. 2(4): 637-640.ISSN: 2454-1354. DOI: 10.21276/lsa.2016.2.3.9.

[46] Sethuraman G, M. Jeganathan, P. Satheesh Kumar and J. Ashok. 2016. A study on air quality assessment of Neyveli, Tamilnadu, India. IAJMR.2 (4): 693-697.ISSN: 2454-1370. DOI: 10.21276/iajmr.2016.2.3.3.

[47] Malarvannan J, C. Sivasubramanian, R. Sivasankar, M. Jeganathan and M. Balakumari. 2016. Shading of building as a preventive measure for passive cooling and energy conservation – A case study. Indo – Asian Journal of Multidisciplinary Research (IAJMR): ISSN: 2454-1370. Volume – 2; Issue - 6; Year – 2016; Page: 906 – 910. DOI: 10.21276.iajmr.2016.2.6.10.

[48] Malarvannan J, C. Sivasubramanian, R. Sivasankar, M. Jeganathan and M. Balakumari. 2016. Assessment of water resource consumption in building construction in tamilnadu, India. Life Science Archives (LSA) ISSN: 2454-1354 Volume – 2; Issue - 6; Year – 2016; Page: 827 – 831 DOI: 10.21276/lsa.2016.2.6.7.

[49] Sivasankar R, C. Sivasubramanian, J. Malarvannan, M. Jeganathan and M. Balakumari. 2016. A Study on water conservation aspects of green buildings. Life Science Archives (LSA),ISSN: 2454-1354. Volume – 2; Issue - 6; Year – 2016; Page: 832 – 836, DOI: 10.21276/lsa.2016.2.6.8.

[50] Ashok J , S. Senthamil Kumar , P. Satheesh Kumar and M. Jeganathan. 2016. Analysis and design of heat resistant in building structures. Life Science Archives (LSA), ISSN: 2454-1354. Volume – 2; Issue - 6; Year – 2016; Page: 842 – 847. DOI: 10.21276/lsa.2016.2.6.10.