EXPERIMENTAL INVESTIGATION OF SELECTIVE CATALYTIC REDUCTION IN A CI ENGINE

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Abstract—

Air pollution is one of the serious problems in India. India is a developing country which is facing the various industrial problems, including the pollution of incomplete combustion which results in increasing air pollution. Due to the high proportion of NO_x emissions generated by road traffic, current and future legislation on NO_x limits has a major impact on the automotive industry. Selective catalytic reduction setup is used to reduce the Nox by inducing NH3 into the chamber by dosing unit. The catalyst the substrate shape and the catalyst material have been varied and the test was conducted. It also tries to establish which catalyst design and structure provide the best solution with respect to installation space, pressure loss and effectiveness. The SCRsystems were defined on the basis of tests carried out with a SINGLE CYLINDER FOUR STROKE KIRLOSKAR ENGINE.

Keywords- Selective Catalytic Reduction, Urea Injector, Substrate (zeolite / potassium sulphate / magnesium sulphate) and Electronic Control Unit.

I. INTRODUCTION

Off late, the economic and industrial growth has caused significant reduction in the quality of ambient air. Internal combustion engines generate undesirable emissions during the combustion process. In this, both SI and CI engines are equally responsible for the same. The emissions exhausted into the surroundings pollute the atmosphere and cause serious problems. The main sources of emission from the engine are from the engine exhaust system and other from the crankcase. The former is the main cause of air pollution. The main constituents of the engine exhaust gases are unburnt hydrocarbons, carbon-di-oxide, carbon monoxide, oxides of nitrogen and particulate matter. Diesel (compression-ignition) engines can be run at higher compression ratios, which result in higher thermal efficiencies compared to gasoline (spark-ignition) engines. Selective catalytic reduction (SCR) systems are the most effective and commonly used post-combustion Nox reduction processes available. SCRs utilize a chemical reaction where vaporized ammonia (NH3) is injected, via an ammonia injection grid, into the exhaust gas prior to flowing through catalytic modules. The objective is to convert nitrogen oxides (Nox), to nitrogen and water. The key to optimizing the chemical reaction within the SCR is achieving uniformity of exhaust gas flow rate.In this paper I am going to deals with the two different type of selective catalytic reduction setup has been used and the result have taken. The catalyst material have betogether formed size and shape have been varied to check variation of the results. These entiretests have been conducted in the single cylinder four stroke kirloskarengine.The exhaust gas temperature is generally a key variable for urea-SCR systems since it affects the activation of the catalyst.(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).

Diesel emissions contain several percent of O2, but almost no reducing gas moreover, the temperature of diesel emissions is much lower (200C) than that of the tail gas from Otto engines. The requirements for the catalytic abatement of nitrogen oxides from diesel emissions therefore, differ significantly from those for Otto engines in two important respects:
(1) The catalyst has to be more active and
(2) A reductant has to be provided.
Moreover, a catalyst for ‘‘cleaning’’ diesel tail gas also has to be highly selective, directing the added reducing agents towards NOx (present as a few hundred ppm) rather than O2 (present as several %). The catalyst must also be active in the presence of water vapor, and direct Nox reduction to the desired products: N2 and H2O. The reduction of NOx is known to include a number of steps. With many catalysts of practical interest the final step is the formation of N2 by decomposition of ammonium nitrite. Decomposition of NH4NO2 occurs efficiently at 100C, and ateven lower temperature in an acidic environment. Formation of ammonium nitrite takes place in the presence of ammonia which acts as a reductant. Three basic strategies have been described to provide this reductant:
(a) Ammonia injection (e.g. by decomposing urea present in a
urea/water slurry) into the tail gas.

(b) Reduction of NO_x that has been trapped on an oxide surface as nitrates, to ammonia by intermittent exposure to a reducing gas.

(c) Injection of a convenient reductant in combination with a

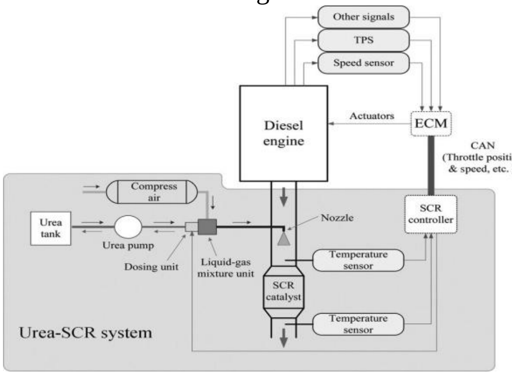
Selective catalyst that will reduce 50% of the NO_x to NH_3.

This ammonia then acts as a reductant for the remaining NO_x.

While the present paper focuses on issues and data directly related to strategy(c), it also provides data that are of relevance to strategies (a) and (b).

In addition, the SV was optimized to promote NO_x conversion to N_2. However, the main efforts here were focused on developing catalytic materials that adsorbed more NH_3, and thus had higher catalytic efficiency than currently used materials. Several authors have investigated ways to improve the conversion rate and several devices have been developed, e.g. for maintaining the exhaust gas temperature and adjusting the NO_2:NO ratio. However, few published studies have reported improvements to the catalyst and no such previous studies have focused on operation of the system under transitional conditions. Thus, the results presented here could be of wide interest.

Fig.1



II. CATALYST IMPROVEMENT

A. CATALYST-1

Zeolite are generally synthesized from sodiumaluminosilcate gel prepared from various silica andalumina and some of the factors that determine the typeof synthetic zeolite produced, are time of reaction,temperature, pressure, and synthesis conditions (like theorder of mixing, gel aging, and stirring). The zeolite properties as given below:

Channels 2.2-8 Å

Cavities 6.6-11.8 Å

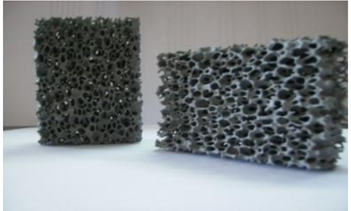
Thermal stability 500-1,000 °C

Ion-exchange capacity Up to 700 milliequivalents/100 g

Surface area Up to 900 m^2/g

Water capacity 1 to 25 wt %

Fig.3

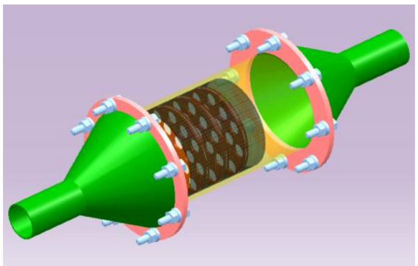


Zeolite can besynthesized with SiO_2 higher or lower than in nature forthe same frame work type. Lower SiO_2 gives greatercation exchange capacity and higher absorbance for polarmolecules, such as used to remove CO_2 (a greenhousegas). Zeolite NaA generally has low silica to aluminaratio and a high ion-exchange capacity. It also isemployed to adsorb other polar molecules in separationand purification application. In this paper we are dealing with the conversion rate of Nox by using two different types of catalyst. Zeolite which is mixed partially with kaolin as a binder. This kaolin is used to holds the zeolite catalyst to bond together to the substrate. And this zeolite is coated in the substrate which has 20 holes per square centimeter. The substrate is arranged inside so as to avoid the back pressure. The hole diameter is of 2mm and the space required for the exhaust gas reaction is increased.

B. CATALYST-2

In this the substrate shape has been changed and it is cylindrical in shape. In this substrate potassium sulphate which mixed with magnesium sulphate as a binder is coated. The substrate is of cylindrical in shape which has a diameter of 100mm and it contains 18 holes of diameter 16mm. It consists of 8plates coated and connected in stud. And these total reactors have been inserted into a cylindrical chamber. This figure represents the reactor setup with potassium coated.

Fig.2



By varying these two chamber we can able to analysis the results. In this system, if the added urea is completely converted to NH3 and uniformly mixed, the NH3 concentration should be about 300 ppm, but measured concentrations at the three monitoring points ranged from about 150 to 50 ppm, indicating that only c. 20 per cent of the urea in the solution was converted to NH3. These results indicate that too low amounts of NH3 may be supplied to the catalyst compared with the amount of NOx present. NH3 generated by urea has been estimated tooccur on the SCR catalyst owing to lag timesbetween injections of urea solution and consequentreductions in the NOx and only c. 20 per centconversion of NH3 at the front of the SCR catalyst.During transient operation, sudden increases inNOx levels may occur, and NOx reduction will beincomplete if insufficient NH3 is injected to reactwith the increased amounts of NOx present in theexhaust gases. However, if the amount of NH3adsorbed on the catalyst could be increased, therecould be sufficient reserves of NH3 to meet suddenincreases in NOx generation. Increasing the NH3adsorption capacity could also enhance NOx reductionrates under steady state conditions, since theurea solution injected upstream of the NOx reduction catalyst is never immediately converted to NH3.The performance of a catalyst is strongly dependenton the catalytic metal and other materials usedto construct it, and the geometry of the system,which is generally based on the results of experimentalinvestigations. Optimizing catalyst specificationsand design generally requires huge expenditures of time and labour for prototyping, evaluation,compounding, and testing. However, the efficiencyof developmental processes can be improved andthe time required can be reduced.

Table.1

	Preparation method of active metal	*Base material*	*Substrate size*	*Substrate weight*
SCR A	Conventional	Conventional	Round	3000gm
SCR B	New	New	rectangle	800gm

III. METHODOLOGY

Engine: The NOx reduction process starts with an efficient CRD engine design that burns clean Ultra Low Sulphur Diesel (ULSD) and produces inherently lower exhaust emissions exhaust that is already much cleaner due to leaner and more complete combustion.

Diesel Exhaust Fluid (DEF) tank and pump: Under the direction of the vehicle's onboard computer, DEF is delivered in precisely metered spray patterns into the exhaust stream just ahead of the SCR converter.

SCR Catalytic Converter: This is where the conversion happens. Exhaust gases and an atomized mist of DEF enter the converter simultaneously. Together with the catalyst inside the converter, the mixture undergoes a chemical reaction that produces nitrogen gas and water vapour.

Control device: Exhaust gases are monitored via a sensor as they leave the SCR catalyst. Feedback is supplied to the main computer to alter the DEF flow if NOx levels fluctuate beyond acceptable parameters.

Chemistry: The NO_x reduction reaction takes place as the gases pass through the catalyst chamber. Before entering the catalyst chamber the ammonia, or other reductant (such as urea), is injected and mixed with the gases. The chemical equation for a stoichiometric reaction using either anhydrous or aqueous ammonia for a selective catalytic reduction process is:

$$4NO + 4NH_3 + 3O_2 \rightarrow 4N_2 + 6H_2O$$
$$2NO_2 + 4NH_3 + 3O_2 \rightarrow 3N_2 + 6H_2O$$
$$NO + NO_2 + 2NH_3 \rightarrow 2N_2 + 3H_2O$$

With several secondary reactions:

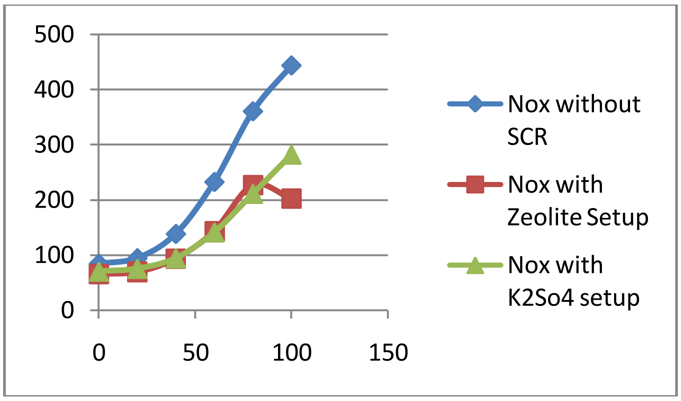
$$2SO_2 + O_2 \rightarrow 2SO_3$$
$$2NH_3 + SO_3 + H_2O \rightarrow (NH_4)_2SO_4$$
$$NH_3 + SO_3 + H_2O \rightarrow NH_4HSO_4$$

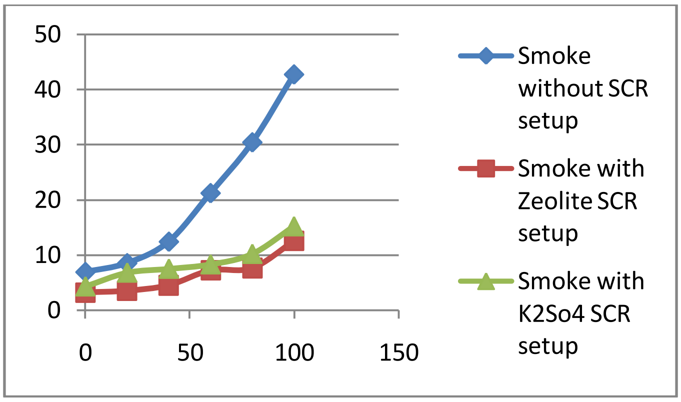
The reaction for urea instead of either anhydrous or aqueous ammonia is:

$$4NO + 2(NH_2)_2CO + O_2 \rightarrow 4N_2 + 4H_2O + 2CO_2$$

The ideal reaction has an optimal temperature range between 630 and 720 K, but can operate from 500 to 720 K with longer residence times. The minimum effective temperature depends on the various fuels, gas constituents and catalyst geometry. Other possible reductant includes cyanuric acid and ammonium sulphate.(Manikandan et.al., 2016, Sethuraman et.al., 2016, Senthil Thambi et.al., 2016, Ashok et.al., 2018, Senthilkumar et.al., 2018, Sundar and Jeganathan 2019 & 2020, Anandan et.al., 2019, Murugavel et.al., 2019, Arokiaswamy et.al., 2019 & 2020, Ganesh Babu et.al., 2020, Gomathi et.al., 2019 & 2020, Manju et.al., 2020, Leema Rose et.al., 2020).

IV. RESULT





V. CONCLUSION

The SCR thus serves as an effective after-treatment for diesel engine.In SCR setup, two different metal oxide catalysts like zeolite and potassium sulphate (coated form) were used for NO_x reduction. With both these catalysts, it gives better NO_x reduction, with decrease in HC and CO emissions and acceptable reduction in brake thermal efficiency. Performance was good when we go for higher α value, and NO_x reduction was better when we go for lower α value.

From the table observation, it has been concluded that catalyst used was slight better in both performance as well as emissions when compared with two catalyst. Hence, the emission, combustion and performance characteristics were good for the test engine being operated with diesel fuel by adapting urea-SCR instead operating.

VI. SCOPE FOR FUTURE WORK

SCR optimization with different reducing agents- In the present work, SCR operation was conducted with Urea as a reducing agent. In future, SCR optimization can be done with different reducing agents for better conversion efficiency.

Study of the geometry of the catalyst and their thermal stability effects- Catalytic activity not only depends upon the chemical composition and operating temperature, but also on their geometry. A study can be conducted by using catalyst of varying geometry in the SCR catalytic converter.

Combining DPF, EGR and SCR for clean engine emission- With a combination of EGR and SCR to reduce NO_x emission showed the marginal increase in smoke emission in the present work. So as to reduce smoke emission along with NOx emission, DPF technique can be adopted along with EGR and SCR.

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VIII. REFERENCES

1. Stefanie Tamma, Hanna H. Ingelsten, Magnus Skoglundh, and Anders E.C. Palmqvist. (2009). The influence of gas phase reactions on the design criteria for catalysts for lean NOx reduction with dimethyl ether.
2. Zhongbiao Wu, Boqiong Jiang, Yue Liu, Weirong Zhao and Baohong Guan. (2006). Experimental study on a low-temperature SCR catalyst base on MnO*x*/TiO2 prepared by sol–gel method

3. Atsushi Kayo, Tsutomu Yamaguchi, and Kozo Tanabe. (1983). The Effect of Preparation Method on the Acidic and Catalytic Properties of Iron Oxide.
4. Yong Miao, Lea-Der Chen,Yongsheng He, Tang-weiKuo. (2009). Study of SCR cold-start by energy method.
5. Tetsuya Nanba, Ken-ichi Wada, ShouichiMasukawa, Junko Uchisawa, Akira Obuchi. (2010). Enhancement of activity of Ir catalysts for selective catalytic reduction of NO with CO by physical mixing with SiO2.
6. Gabriela Carja, Yoshikazu Kameshima, Kiyoshi Okada, Changalla.DMadhusoodhana. (2007). Mn-Ce/ZSM-5 as a new superior catalyst for NO reduction with NH_3.
7. Lifeng Xu, Robert W. McCabe, Robert H. Hammerle. (2002). NOx self- inhibition in selective catalytic reduction with urea (ammonia) over a Cu-zeolite catalyst in diesel exhaust.
8. 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.
9. 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.
10. 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.
11. 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.
12. 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.
13. 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.
14. 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/.
15. 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/
16. 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.
17. 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.
18. 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.
19. 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.
20. 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.
21. 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.
22. 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.
23. 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.
24. 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.
25. 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.

26. 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.
27. 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.
28. 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.
29. 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.
30. 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.
31. 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.
32. 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.
33. 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.
34. 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.
35. 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.
36. 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.
37. 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.
38. Senthil Thambi J, C. Sivasubramanian and M. Jeganathan. 2018. Ambient Air quality monitoring in terms of (Nitrogen di oxide in and around Ariyalur District, Tamilnadu, India. IAJMR.4 (3): 1414-1417.ISSN: 2454-1370. DOI: 10.22192/iajmr.2018.4.3.2.
39. 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.
40. 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.
41. 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.
42. 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.

APPENDIX-1

TEST ENGINE

Make and Model : Kirloskar, AV1 make
General Details : Four stroke, Compression ignition, Vertical,
Constant speed, water cooled,
Direct injection.
Number of cylinders : One
Bore : 80 mm
Stroke : 110 mm
Swept Volume : 553 cc
Clearance Volume : 36.87 cc
Compression ratio : 16.5: 1
Rated Output : 3.7 kW @ 1500rpm
Rated Speed : 1500 rpm
Injection pressure : 220 bar
Fuel injection timing : 23 BTDC
Type of combustion chamber : Hemispherical open combustion chamber
Fuel : High speed diesel
Lubricating oil : SAE 40
Connecting rod length : 235 mm
Valve diameter : 33.7 mm
Maximum Valve lift : 10.2 mm