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Nitrogen Oxide Emission from HCCI Combustion using Palm Oil Biodiesel Blended with RON 97 as Fuel

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Abstract **– This paper presents nitrogen oxide analysis in modified diesel engine to get homogenous charge compression ignition (HCCI) combustion. In effected of fuel blending value used in testing, a nitrogen oxide measured at started of change of fuel using switch changing fuel. Using 70% palm oil biodiesel and 30% RON 97. At first of absorption of NOx, measurement using Automobile gas analyser. 30 sample of experiment to measure HCCI combustion emission. The experimental results indicate that the maximum NOx release, minimum NOx release and average NOx release of 70% palm oil biodiesel and 30% RON 97 in HCCI combustion significantly increase from test 1 to test 3. The NOx showed HCCI combustion with intake air boost are far lower than diesel engine. Specifically, the NOx emissions can be maintained within 100 ppm, and the soot emissions are below 30 % at the full load ranges.**

Keywords **– HCCI, Palm oil biodiesel, RON 97 and NOx.**

I. INTRODUCTION

Homogenous charge Combustion ignition (HCCI) engines are being considered as an alternative to diesel engines. The HCCI concept involves premixing fuel and air prior to induction in to the cylinder. HCCI combustion was finding as new way for two stroke engines. A first research on such type of combustion process was made by Onishi et al. in 1979 [1]. This completely new type of combustion adopted to the piston engines has been called Active Thermo Atmosphere Combustion as a promising alternative for existing spark and diesel engines. After that Onishi presentation the same combustion process was demonstrated at Toyota. The spectroscopic analysis of HCCI combustion process was performed in opposed piston two stroke engine. It was discovered that HCCI combustion is suitable to two stroke engines at part load conditions, and the overall burn rates are very fast. It was noticed that combustion in HCCI engines is extremely smooth and the engine had excellent low fuel consumption together with low exhaust emissions in the HCCI mode operation. Carbon Monoxide (CO) is a very dangerous substance since it reduces the oxygen carrying capacity of blood stream. High flame temperature generated during the combustion process is responsible for NOx formation. [2]. Experiments were performed with blends of paraffinic and aromatic fuels over a range of engine speed and dilution levels. The process was analysed, considering that HCCI is mainly controlled by chemical kinetics excepting negligible influence from physical effects, first of all turbulence and mixing. During the researches, a simplified kinetics model was used to predict heat release as a function of pressure, temperature, and species concentration in the combustion chamber. This assumption permitted to show that the HCCI combustion could be divided into two semi-independent processes: ignition and bulk energy release. It was concluded that HCCI self-ignition is controlled by the same low temperature (below 1000K) chemistry leading to knock in SI engines, and that the bulk energy release is controlled by the high temperature (above 1000K) chemistry, dominated by CO oxidation. Wing et al also study, an electrical dynamometer assembled on a four-cylinder and four stroke indirect injection diesel engine has been used. In addition, there are two exhaust emission measurement systems working independently for ascertaining the levels of HC, CO, CO2, and NOx respectively.

Chiatti et al. [3] have carried out a study to evaluate the vibration characteristics in a two-cylinder, water-cooled and common-rail diesel engine fuelled with different biodiesel blends (B10, B20 and B40). The study showed that the vibration signals can be used as a real time management and feedback to the control unit to correct the injection parameters setting when the engine is fuelled with biodiesel fuel. Furthermore, an experiment study on engine vibration was performed by Taghizadeh-Alisaraei et al. [4] in a four-stroke, six-cylinder heavy-duty diesel engine with biodiesel blends and diesel fuels from 1000 to 2200 rpm. The experiments demonstrated that B40 and B20 have the lowest engine vibration with 45.02 and 46.06 m^2/s, respectively as compared to diesel. Antoni et al [5] showed that better pressure reconstruction is possible by taking into account the non-stationary nature of the vibration signals [6].

In comparison with SI and CI, HCCI engine has much higher part load efficiency, zero particular matters and very low NOx emissions (less than 10 ppm – compared to >500 ppm for diesel engines) [7], as a result of use dilute air fuel mixture. In HCCI engine there is no problem with soot formation due to the use of homogeneous charge. HCCI engines can be operating on gasoline, diesel fuel and, what is very important, on most alternative fuels. If the control issues are successfully addressed, HCCI would combine low fuel consumption, comparable (or better) to the best Diesel Engines. HCCI is an attractive advanced combustion process that offers the potential for substantial simultaneous reduction of both NOx and PM, while still providing high diesel – like efficiencies. In HCCI engines, combustion occurs as a result of spontaneous auto – ignition at multiple points throughout the volume of the in cylinder charge gas. This unique property of HCCI allows the combustion of very lean or dilute mixtures, resulting in low bulk as well as local combustion temperatures that dramatically reduce engine – out NOx emissions. [8].

II. Experimental Setup

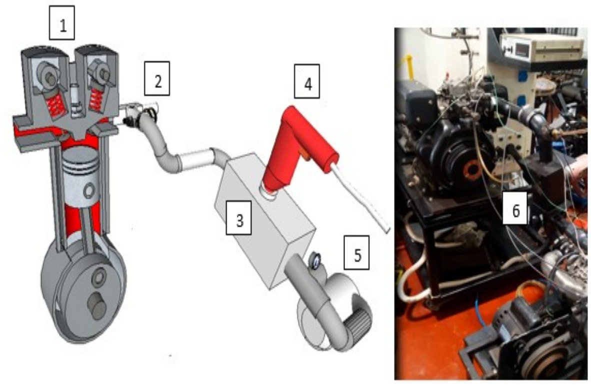

Fig. 1. Design of experiment. 1- HCCI engine, 2 – Fuel mixer and fuel direct injection intake, 3- air heater, 4- industrial heater, 5 – air compressor and 6 - actual experiment setup.

Figure 1 shows design of experiment and actual HCCI engine installed at dynamometer equipment. Modified diesel engine are use in experiment to get HCCI combustion. In this experiment, emission data was collected using gas analyser. RPM, air compressor pressure and temperature of intake manifold was setup to 3000 rpm, 1.5 bar air pressure and 160° C. Fuel blending is 70% palm oil biodiesel and 30% RON 97 (petrol) set as fuel. There are 30 testing of HCCI combustion to get result on NOx. Modified diesel engine running using diesel fuel for get optimum temperature before engine switch to HCCI fuel. Automobile emission analyser were used to detect NOx in HCCI combustion. Below in Table 1 shows specification an equipment of gas analyser and figure 2 shows gas analyser and Table 1 showed specification of modified diesel engine.

Table 1: specification gas analyser of HCCI engine

Gas Analyser	**AUTOCHECK 974/5 Gas**
Measurement Range	HC : 0~10,000ppm(hexane)
	0~20,000ppm(propane)
	NOx : 0~5000ppm(Option)
Power	90~264VAC, 43~63Hz or 12VDC
Dimension	270(W) × 240(H) × 410(D)mm

Fig. 2. Automobile Emission analyzer

Table 2: Specification of test engine

Model	**KM 186 f (A) Diesel**
Type	In line cylinder, 4 stroke, air cooler, direct injection
Bore x Stroke mm	86 X 70
Piston displacement L	0.406 (0.418)
Rated power/ rated speed kW/r/min	5.7/3000
	6.3/3600
Max Torque N.m/r/min	18.7/2880
Fuel consumption/rated speed g/(kW.h)/r/min	275.1/3000
	281.5/3600
Fuel consumption/(kW.h)	≤4.08
Piston average speed/ rotate speed m/s/r/min	7.0/3000
	8.4/3600
Compression Ratio	19:1

III. Result and Discussion

The result of NOx such as part per million (ppm) well as variable of operating parameters were determined. In addition, NOx value analysis of HCCI combustion, whose profile for range of mix 70% palm oil biodiesel and 30% RON 97 was tested during experiment. The results of experiments were shows in figure 4 as below:-

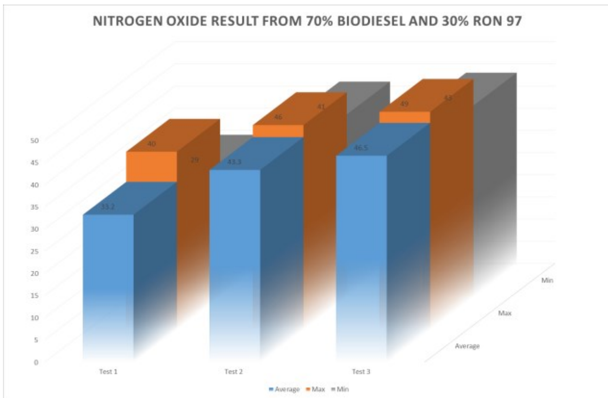

Fig. 4. Average, Maximum and Minimum of NOx.

In figure 4 shows average, maximum and minimum of NOx between test 1, test 2 and test 3. This graph pattern showed increasing of NOx (average) from experiment sample test 1, test 2 and test 3. From data of average NOx showed an increase value from 33.2 ppm to 46.5 ppm is 38%. For maximum NOx value is 40 ppm to 49 ppm and for minimum value is 29 ppm to 43 ppm. This is NOx value influence by effective of temperature in intake manifold, mixture of fuel and pressure of air in intake manifold. This result similar with Xingcai Lu et al [9] where experimental study on compound HCCI combustion fuelled with gasoline and diesel blends showed NOx in range same as experimental. Experiment also compared with Suyin Gan et al [10] which study HCCI combustion in direct injection diesel engines using early, multiple and late injection strategies. Governing factors in HCCI operations such as injector characteristics, injection pressure, piston bowl geometry, compression ratio, intake charge temperature, exhaust gas recirculation (EGR) and supercharging or turbocharging, where all factors influencing the percentage of emission and pollutants.

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IV. Conclusion

The presence of saturated components, design of intake manifold and the degree of unsaturation, volatility and the oxygen content in an oxygenated hydrocarbon fuel plays an important role in determining of NOx characteristics. It was observed that more the percentage of blending fuel, more easy to get complete combustion with low temperature. This result shows that it can use for HCCI engine because it will produce low NOx. With the increase in the degree of calorific value, the fuel combustion rate and emission of NOx increased. Insights obtained from this study coupled with an in-depth study in an engine environment will be helpful to underpin NOx emissions behavior of palm oil methyl ester fuel blends.

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Authors' Profiles

First Author A. Awaludin from Kuala Lumpur Malaysia. He works as Senior Researcher at FGV AT Sdn Bhd. received his bachelor's degree in Mechanical Engineering with honours in 2003 at University Kebangsaan Malaysia. He also received his Master' Degree in 2007 from University Putra Malaysia. His experience about 25 year in Oil Palm Industry. His main research interests focused on palm oil mechanization system, design robotic palm oil harvester, small gasification system, and renewable energy. He also doing research in palm oil milling process, biodiesel combustion engine and HCCI combustion.

Second Author Mohd Zaki Nuawi is an associate Professor in the Faculty of Engineering and Built Environment at the Universiti Kebangsaan Malaysia where he has been a faculty member since 1997. He completed his Ph.D. at Universiti Kebangsaan Malaysia and his undergraduate and master level studies at University of Picardie, France. His research interests lie in the area of sound and vibration for machine/machining condition monitoring, signal analysis ranging from theory to design to implementation. His research interests tend to be of multidisciplinary nature and rather eclectic. He has collaborated actively with researchers in several other disciplines of energy harvesting, sensor application particularly piezo-film sensor. He has a significant track of high-profile publications with more 200 scientific papers. He led around 13 research projects and involved in 53 projects as co-researcher. M Z Nuawi has served on many conference and workshop program committees and is the Conference Chair for NVC 2015, NVC 2012 and NVC 2010. He has served on the Scientific Committee ReCAR 2017, 2015, 2013"No life without signals"

Third Author Ing. Dr. Mohd Faisal Hushim, an SAE International member, received his bachelor's degree in Mechanical Engineering with honours in 2008. Then he completed his Ph.D. in Mechanical Engineering (Automotive Engineering) in 2013. Ing. Faisal is a member for several national and international professional bodies. His main research interests focused on fuelling system, automotive performance characteristics, small gasoline technologies, and renewable energy. He has been invited to act as speaker and a reviewer for national and international journals also conferences as well. He is an active reviewer for Journal of Automobile Engineering and SAE International. His main research interests focused on fuelling system, automotive performance characteristics, small gasoline technologies, and renewable energy. The findings of his research have been acknowledged by several professional bodies and committees by resulting him to won several awards in several technical expos and exhibitions: Silver Award at the 14th Industrial Art and Technology Exhibition (INATEX 2012), and two awards (Gold Award and Best Award) at the Malaysia Technology Expo (MTE 2013). His research product has been patented by Malaysia Patent in 2013.