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Experimental Setup in Study for HCCI Engine Vibration using I-kaz^{TM} Method and using Palm Oil Biodiesel Blended with RON 97 as Fuel

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Abstract **– This paper presents work conducted at the Universiti Kebangsaan Malaysia to support of the HCCI Engine Program. The objective of this paper is to develop an engine that employs Homogeneous Charge Compression Ignition (HCCI) combustion and features using Palm Oil Methyl ester as fuel. A Novel of palm oil product using for HCCI engine fuel was investigated in vibration signal using RIONOTE hardware and Mathlab (I-kaz Vibro). Percentage of blend of Palm Oil Methyl Ester and RON 97 based on 0%, 5%, 10%, 20%, and 30% percentage blended. Result will be showed in comparison between blended fuel to power, torque, and fuel consumption (measured by dynamometer) with vibration signal produce during HCCI combustion. Conclusion of experiment analysing vibration signal will show the experimental plan is feasible and reasonable.**

Keywords **– Homogeneous charge compression ignition, palm biodiesel, Methyl Ester, Vibration and blended fuel.**

I. Introduction

Homogeneous charge compression ignition (HCCI) engine uses new mode of combustion technology and new green fuel. In basic of engine combustion, there is no spark plug or injector to assist the combustion, and the combustion auto-ignites in multiple spots once the mixture has reached its chemical activation energy using high pressure raised in combustion chamber. There are many challenges in developing HCCI engines because HCCI engine are difficult to control the auto-ignition of the mixture and difficult in achieving a cold start, meeting emission standards and controlling knock [1]. HCCI combustion was discovered as an alternative way for two stroke engines. A first study on such type of combustion process was made by Onishi et al. in 1979 [2]. 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. The drawbacks of two stroke engines are a high residuals emissions at low and partially loads, and the tendency to run on (knock effect) when the engine is stopped. Onishi and co-workers turned these deficiencies into strengths by devising a combustion mode that relied on both high levels of internal residuals and high initial charge temperature. By creating conditions that led to spontaneous ignition of charge they obtained significant reduction in emissions and an improvement in fuel consumptions. The HCCI technique is the process by which a homogeneous mixture of air and fuel is compressed until auto-ignition occurs near the end of the compression stroke, followed by a combustion process that is significantly faster than either Compression Ignition (CI) or Spark Ignition (SI) combustion [3].

The vibrations caused at the engine are two types they are torsional and longitudinal vibrations. Engines always have some degree of torsional vibration during operation due to their reciprocating nature. The rotation of crankshaft of an engine increases the cylinder pressure as the piston approaches top dead centre (TDC) on the compression stroke. Ignition and combustion increases the pressure just after TDC and the pressure starts to decrease when the piston moves down to bottom dead centre (BDC). The pressure on the piston generates the tangential force that does useful work and increases the rotational speed of the crankshaft during this combustion stroke, whereas the compression stroke decreases the engine's angular velocity. The changing rotational speed results in the speed fluctuations of the crankshaft and the torsional vibrations at the crankshaft. The reciprocating and rotating components of engine have subjected to variation in inertial motion and the combustion pressure during the operation and the variation in the inertial motion of the parts during the upward motion and variation in the combustion pressure during the downward motion produce the unbalanced forces at the engine block and the unbalanced forces at the block are measured as longitudinal vibrations in the three orthogonal direction [4].

Chiatti et al. [5] 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. [6] in a four-stroke, six-cylinder heavy-duty diesel engine with biodiesel blends and diesel fuels from 1000 to 2200 rpm. The conditions of engine vibration were compared before and after the engine services. They reported that the total vibration values were reduced significantly after servicing the engine by 12% and most of vibration accelerations rising were between 1800 and 2000 rpm. The experiments demonstrated that B40 and B20 have the lowest engine vibration with 45.02 and 46.06 m2/s, respectively as compared to diesel. The pressure signal reconstruction from the engine block vibration has been recognized as a difficult issue due to highly nonlinear relation between cylinder pressure evolution and vibration signal. For this purpose, signal deconvolution or inverse filtering provides quite good results. Antoni et al [7] showed that better pressure reconstruction is possible by taking into account the nonstationary nature of the vibration signals [8].

The structural vibration signal simultaneously collects information on several cylinders. Urlaub and B¨ohme proposed an algorithm to estimate pressures in each cylinder from the structure-borne sound recorded on the surface of the engine block [9]. Grondin.O et al presented a method to estimate and to control the combustion timing of a Diesel HCCI engine without cylinder pressure sensor. The combustion state estimator relies on a high frequency periodic observer that take as input the vibration signal recorded on the engine bloc with a knock sensor. It gives the estimated values of the noise and of the combustion timing [10]. The vibration diagnostic system described in this paper has been constructed using RION hardware and Mathlab software and is designed for easy vibration wave capture.

II. Problem of HCCI Engines

A. High cylinder pressures require stronger engine construction (expensive).
B. More limited power range than a conventional spark engine.
C. The many phases of combustion characteristics are difficult (and more expansion) to control.

III. Design of Vibration Signal Collection System

Design of vibration signal collection method using accelerator meter in this study. Fig 1 showed diagram design of collection data of vibration.

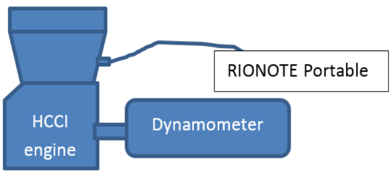


Fig. 1. Design of vibration signal collection system

Collection vibration signal of engine through accelerometer and recorded by RIONOTE hardware. I-kaz^{TM} vibro as Mathlab cording will be used to analysis vibration from HCCI engine. Below in figure 2 showed a specification of RIONOTE hardware

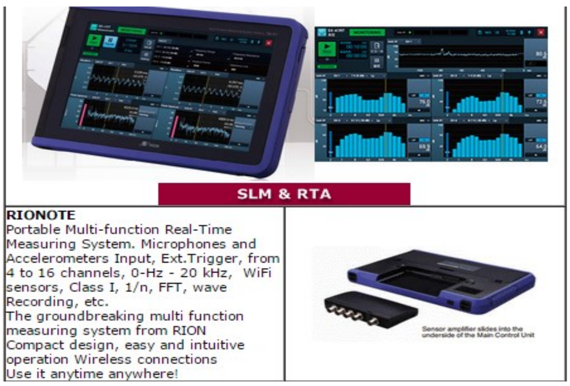


Fig. 2. RIONOTE specification.

IV. Progress on Experimental Setup

The experimental work was carried out with a single-cylinder engine (modified to HCCI), supercharged, low pressure injector (control by pulse current generator) and high pressure injector for biodiesel. A 7.5 kW asynchronous dynamometer was used to maintain the variation of loads at different speeds and loads. Assessment on the engine performance will be done using an asynchronous GUNT dynamometer as shown in Figure 3. Main parameters to be evaluated, at different engine speeds are: engine torque, brake power, volumetric fuel consumption, air/fuel ratio, thermal efficiency and brake mean effective pressure. Also shown in Figure 4 is the specialized metal connector, which has been fabricated to connect the dynamometer with the test engine.

Fig. 3: Engine test rig based on GUNT asynchronous dynamometer

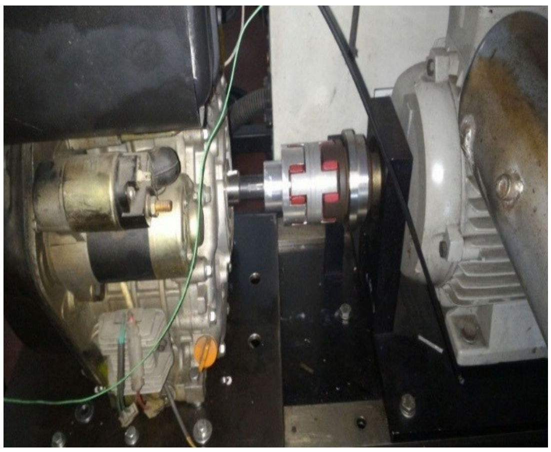


Fig. 4. Connector between the test engine and dynamometer

The intake airflow was installing an air heater to give low temperature in intake manifold. The air pressure intake was supplied by supercharge equipment. It give about 1 – 5 bar of air pressure. It also have a relief valve to maintain a suitable pressure in HCCI combustion. In addition, a pressure meter was employed to measure air pressure (figure 5).

Fig. 5. Air Pressure meter – to monitor air pressure

Temperature values of intake manifold and exhaust were measured by using K-type thermocouples. The specifications of the test engine are given in Table 1.

Table 1: Specification of test engine

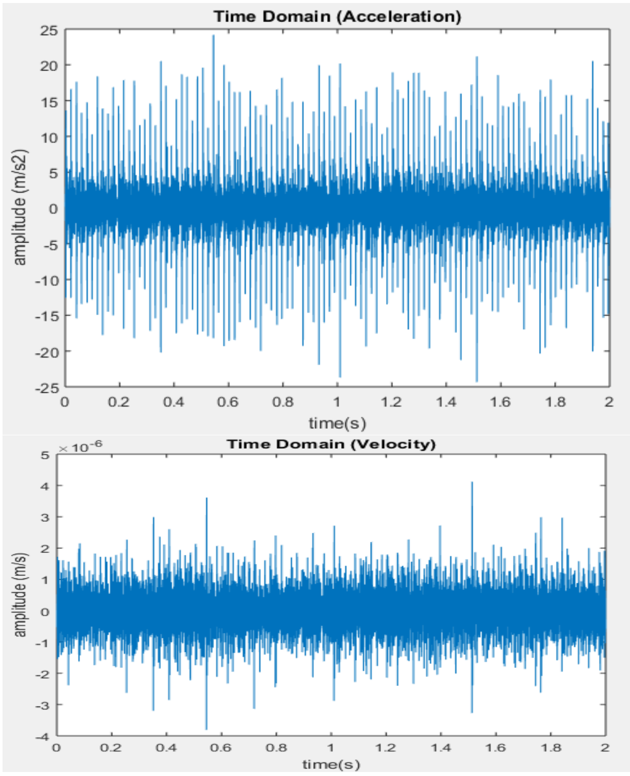
Model	KM 186 f (A) Diesel
Type	In line cylinder, 4 stroke, air cooler, direct injection
Bore x Stroke mm	86 X 70
Piston displacement L	0.406 (0.418)
Rated power/ rated speed kW/r/min	5.7/3000
	6.3/3600
Max Torque N.m/r/min	18.7/2880
Max steady speed at zero – load r/min	≤108% of rated speed
Min steady speed at zero – load r/min	≤1300
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

To carry out the vibration analysis, the speed of engine was recorded with ENDEVCO 751 -100 accelerometer sensor and its signal was recorded with a high speed data acquisition system. The accelerometer sensor was mounted center of cylinder block. Figure 6 showed accelerometer sensor mounting at HCCI engine. Further than that, instrumentation work is still on going, which will enable monitoring and data logging of the main engine operating parameters.

Fig. 6. Accelerometer sensor mounting

V. Expected Result

M.Z Nuawi et al [12] using I-kaz^{TM} statistical method to analysis the results obtained from the accelerometer gauges installed on the engine block and measured value of I-kaz^{TM} coefficient, low frequency kurtosis, high frequency kurtosis and very high frequency kurtosis in different rpm. From that an expected result showed in figure 7. In this figure 7 showed displacement vs time, velocity vs time, acceleration vs time and I-kaz^{TM} vibro as expected result.



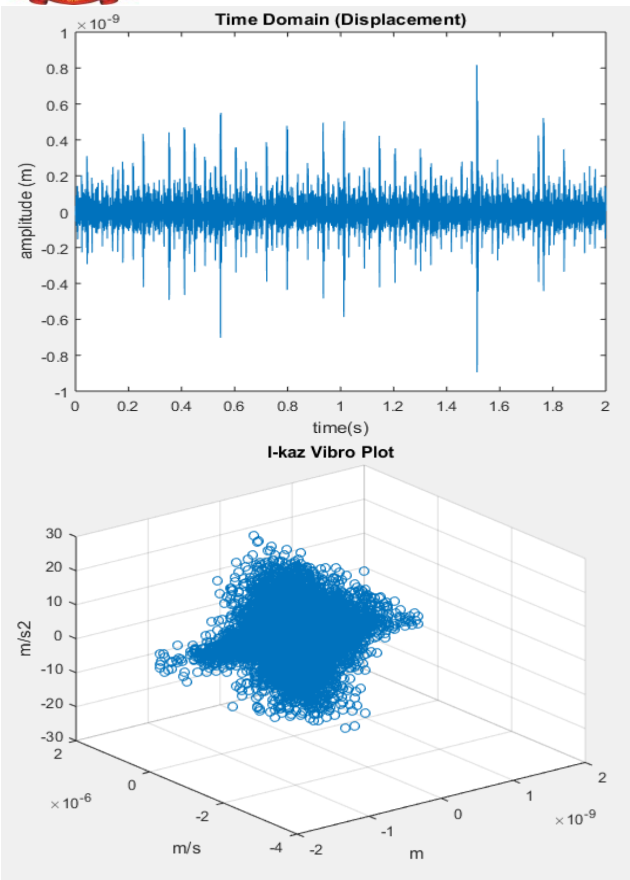


Fig. 7. I-kaz™ expected result

VI. Conclusion

In this paper, the proposed setup and configuration for developing a prototype of HCCI engine using palm biodiesel blended with RON 97 has been described. The status of the current experimental setup and development has also been highlighted. Prior to those, issues involving installation of HCCI engine has also been laid out. From experiment setup result also can predicted in smoothness of experiment in doing research vibration, power in engine performance and emission. The design of experiment will be change due to expected problem if happened.

VII. Acknowledgment

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References

[1] A.Aziz Hairuddin, Talal Yusaf, Andrew P.Wandel, *A review of hydrogen and natural gas addition in diesel HCCI engines.* Renewable and Sustainable Energy Reviews 32(2014)739-761. 2014

[2] Onishi, S.H. Jo, K. Shoda, P.D. Jo, S. Kato, *Active Thermo-Atmosphere Combustion (ATAC) – A New Combustion Process for Internal Combustion Engines 1*, SAE Paper 790501, 1979

[3] Rattanapaibule K, Aung K. *Performance predictions of a hydrogen-enhanced natural gas HCCI engine. In Proceedings of the international* mechanical engineering congress and exposition (IMECE2005). Energy Conversion and Resources.Florida; 2005.p.89–294.

[4] T. Ramachandran, K. P. Padmanaban, *review on internal combustion engine vibrations and mountings*, International Journal of Engineering Sciences & Emerging Technologies, August 2012. ISSN: 2231 – 6604 Volume 3, Issue 1, pp: 63-73.

[5] Chiatti G, Chiavola O, Recco E. *Combustion and vibration characteristics in a small displacement diesel engine fuelled with biodiesel blends*. SAE Technical Paper, 2013-01-1902; 2013.

[6] Taghizadeh-Alisaraei A, Ghobadian B, Tavakoli-Hashjin T, Mohtasebi SS. *Vibration analysis of a diesel engine using biodiesel and petrodiesel fuel blends*. Fuel 2012; 102(0):414e22.

[7] J. Antoni, J. Dani`ere, and F. Guillet, *"Effective vibration analysis of IC engines using cyclostationarity. Part I : A methodology for condition monitoring,"* Journal of Sound and Vibration, vol. 257, no. 5, pp. 815–837, 2002.

[8] J. Antoni, J. Danire, F. Guillet, and R. Randall, *"Effective vibration analysis of IC engines using cyclostationarity. Part II : New results on the reconstruction of the cylinder pressure,"* Journal of Sound and Vibration, vol. 257, no. 5, pp. 839–856, 2002.

[9] M. Urlaub and J. F. B¨ohme, *"Reconstruction of pressure signals on structure-borne sound for knock investigation,"* SAE Paper, no. 2004- 01-0522, 2004.

[10] Olivier Grondin, Jonathan Chauvin, Fabrice Guillemin, Emmanuel Nguyen and Gilles Corde, *Combustion Parameters Estimation and Control Using Vibration Signal : Application to the Diesel HCCI Engine,* Proceedings of the 47th IEEE Conference on Decision and Control Cancun, Mexico, Dec. 9-11, 2008

[11] Information on http://alternativefuels.about.com/od/researchdevelopment/a/HCCIbasics.htm

[12] Arshin Oskoueian and Mohd Zaki Nuawi, *Internal Combustion Engine Monitoring using Strain Gauge and Analyzing with I-kaz,* 2012 2nd International Conference on Mechanical, Industrial and Manufacturing Engineering, IERI Procedia 1(2012) 192 – 198.

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