The Influence of CO_2 in CNG-Diesel as Pilot Fuel in Compression Ignition Engine

Farah Idayu Z.[*], A.Rashid A.Aziz[**], Morgan R.H[**], Firmansyah , Ezrann Z. Zainal A.
[*]*Centre for Automotive Research and Energy Management, Mechanical Department*
[**]*Universiti Teknologi PETRONAS*

***Abstract*— In this study, towards the effort to decrease the emissions of compression ignition engine, lot of researchers come out with many solution to improve the compress ignition engine emissions. In this paper, a brief review how the influence of CO_2 inside the compression ignition engine or diesel engine with compress natural gas (CNG) with diesel as pilot fuel. In other hand, the example of exhaust gas recirculation (EGR) as the influence of high CO_2 into the engine will be explain in this paper.**

***Index Terms*— Diesel Engine, Compression ignition Engine, Compress Natural Gas, Carbon Dioxide.**

I. INTRODUCTION

AS the fuel technology grown up, a cleaner gas has been found. This gas been found for many years ago. However, the usage of this gas have been developed year by year. Britain was the first country to commercialize the use of natural gas. Around 1785, natural gas produced from coal was used to light houses and also the street light. Since 1920's, industry began to use natural gas in manufacturing and processing plants. At the same time, natural gas also have been developed to heat the boilers for generating the electricity[1]. Natural gas is a clean and friendly environment gas. The characteristics of the gas were really helpful to the diesel engine to make the emission more cleaner. It has the potential as an alternative to diesel because the levels of non-methane hydrocarbons (NMHCs) and carbon monoxide (CO) can be decreased through combustion. Though air pollution methane itself is a greenhouse gas, it has clean burning characteristic, allowing high efficiency and low emission. Compared to gasoline burning, it reduces carbon monoxide by 90 to 97%, nitrogen oxide by 35 to 60% and non-methane hydrocarbon emission by 50 to 75% [2].

As we know, there are a lot of case study even the simulation and also the experimental setup had been done to improve the emission in diesel engine. One of the best mixture is by mixing the diesel and the natural gas. Inject the diesel fuel and the natural gas at the same time exactly will improve the engine emissions. It will slightly decrease the performance of the engine. Even the performance were slightly lower than before, in emission characteristic, most of the gases will definitely decrease such as the nitrogen oxides (NOx), carbon monoxide (CO) and also the carbon oxides (CO_2). The ability of the crude natural gas in reduce the CO_2 in emission give the opportunity to this dual fuel more popular among of the diesel fuel.

II. DISCUSSION

A. Alternative gaseous in Diesel Engine with diesel as pilot fuel

Firstly, using the Hydrogen as the medium to make it more cleaner. As we know, Hydrogen were one of the best and cleaner gas that can produce the emission to be more friendly environmental. Previous research has indicated that the addition of hydrogen in the diesel engine improves engine performance because the engine attains leaner operational capacity. Use of hydrogen as secondary fuel enhance the thermal efficiency of the engine at the high load condition and at the same time, it produces reasonably good effect at low conditions[3]. In other hand, NOx emissions for various combinations of diesel-hydrogen in dual-fuel mode were more lower than the pure diesel fuel engine[3]. In one of investigations, worked with hydrogen into the intake port of a single cylinder diesel engine while as an air enrichment medium while diesel as ignition source found that increased in brake thermal efficiency with reduction in emission of NOx in the exhaust[4]. In another Saravanan et. al experiment, he observed 15% rise in brake thermal efficiency at 75% load as compared to pure diesel operation by injecting hydrogen into the intake port of a single cylinder diesel engine while NOx emission was raised by 1-2% at full load condition[5]. In other experiment, the researcher investigated that the dual fuel hydrogen-diesel engine had higher brake thermal efficiency nearer to 40% as compared to original diesel engine by introducing double injector, one for hydrogen and another one for diesel in an injector of a common rail diesel engine[6]. In other hand, other researcher obtained approximately 43% higher fuel efficiency in hydrogen-fuelled engine in comparison with 28% for the conventional diesel engine in addition to 20% reduction in NOx formation than diesel engine due to direct injection of hydrogen in a diesel engine[7].

Using liquid natural gas is a platform to introducing the natural as a secondary fuel in diesel engine. Actually, natural gas also can be used in compressed natural (CNG). In fuel world, CNG were more popular than LPG due to its lower cost. LNG is mainly used for transportation and electricity production[8]. Compared to CNG, LNG offers advantages, such as easier transportation, storage and also safety[8]. As

Kumar. S et al. said, the disadvantages of the LNG are in term of achieving global market share, however, are the lack of infrastructure, harmonized standards and regulation, adoption of the automobile manufacturers and retrofit systems[9]. From the previous investigation, LNG also shown that one of the most viable option for long-range used due to its greater liquefied state compared to the CNG system in terms of economic potential[10,11], environmental aspect as [15] and also technical performance [12,13]. In Kraipat C et. al investigation, the thermal efficiency of the dual fuel operation was less than that of the single fuel operation, averaging less than 3.5%[8]. In terms of the practical speed range of diesel engine, they also said that speed which range less than 1700 rpm, the specific fuel consumption of the dual fuel engine operation was slightly lower than that of the single operation[8]. In Kraipat C et. al investigation, both diesel and dual fuel operations, volumetric efficiency increased with engine speed[8]. The diesel engine operation showed higher volumetric efficiency than dual fuel operation. In other hand, compared to the diesel operation, the dual fuel engine operation showed higher THC and CO emission, while the emissions of NOx and CO_2 were lower[8].

B. Compress Natural Gas (CNG) in Diesel Engine

The natural gas (NG) potential as transition fuel to hydrogen boosting up the NG usage as the secondary fuel in the current automotive industries. Its capability in reducing CO_2 production with less drop in the performance as well as cheaper price create an opportunity for NG to be the primary fuel candidate. However, the attempt to fulfill the requirement for NG fuel cause another obstacle such as the high CO_2 content in the crude NG which considered to be highly corrosive in the methane environment. CO_2 removal from NG so far is the largest separation application worldwide [14]. Investments have been made in order to find the most effective technique with the lowest price. However, there are many alternatives techniques have been offered and yet it is still considered to be a high investments.

Previous Research on high-CO_2 fuel performance shows that the presence of up to 40% CO_2 gas did not deteriorate the engine performance especially in the lean operating condition. High-CO_2 contents also reduce the NOx emission yet increase the hydrocarbon and CO emission [14]. These preliminary results shows that the best performance of the engine with high-CO_2 fuel (crude NG) can be achieved by optimization of the engine parameters in order to get a comparable engine power while maintaining the emission limits.

Natural gas has proven to be one of the promising alternative fuels which when compressed for use in transportation and other applications, is known as compressed natural gas (CNG). It is a gaseous fossil fuel that has been established to belong to clean fuels [15]. Combustion of natural gas produces significantly lower emissions of carbon monoxide, carbon dioxide, non-methane hydrocarbon emissions and particulate matter when compared to diesel and gasoline in engine combustion process [15]. Natural gas comprises of mixture of various gas.

The presence of high amount of carbon dioxide in a mixture of natural gas and carbon dioxide can cause lower heating value of the mixture when compared with natural gas. This leads to reduction in the burning velocity which ultimately affects the performance of the engine [14]. Experiment conducted on a Ricardo engine using methane and carbon dioxide at different compression ratios, speeds and equivalent ratios showed that there is an improvement in NOx emissions. However, lower cylinder pressure obtained led to the reduction in engine power and thermal efficiency and increase in the level of unburnt hydrocarbon [16]. The results obtained in are the same even though different engines and operating conditions are used [16].

C. Exhaust Gas Recirculation (EGR) in Diesel Engine

The NOx effect produced by the presence of carbon dioxide in natural gas is similar to the effect of EGR in spark ignition (SI) engines, compression ignition (CI) engines and homogenous charge compression ignition (HCCI) engines. EGR is one of the common techniques and effective method to control in-cylinder NOx emission in an internal combustion engine. The exhaust gases mainly consist of carbon dioxide, nitrogen etc and the mixture has higher specific heat compared to atmospheric air. In a spark ignition (SI) engine, the recirculated inert exhaust gases displace some of the intake charge entering the combustion chamber, thereby reducing the combustion temperature and NOx formation [17]. In a compression ignition (CI) engine, the inert exhaust gases replace some of the excess oxygen in the pre combustion mixture, thereby decreasing the combustion rate. This automatically reduces the combustion temperature and NOx formation. Several researchers have investigated the effect of EGR on engine performance and exhaust emissions [17,18]. These studies have been performed in spark ignition (SI) engines, compression ignition (CI) engines and homogenous charge compression ignition (HCCI) engines and the result showed that the role of EGR is to reduce NOx emissions.

D. Related Carbon Dioxide (CO_2) in Diesel Engines

The presence of high CO_2 in the mixture of natural gas-carbon dioxide may still not affect much the efficiency of the engine if the right amount of CO_2 is introduced into the mixture. Henham and Makkar found that the efficiency of the mixture of natural gas and carbon dioxide is not much affected up to 37% natural gas substitution [16]. It was reported also that introduction of carbon dioxide more than 40% into the mixture could lead to harsh and irregular running of an engine [16]. Shrestha and Karim also found that the presence of diluents (carbon dioxide) beyond about 50% in the mixture could result to significant drop in the power output of the engine [19].

The low engine performance that results when high CO_2 is present in natural gas-carbon dioxide mixture can be overcome as suggested by numerous research results that it is possible to increase the compression ratio (CR) as a means of improving performance of an engine fueled with biogas when CO_2 is present [19] even though emission of NOx and HC

would increase. However, NOx emission could be tackled by the presence of the high CO_2 content in the fuel. In addition, brake thermal efficiency increases with increase in compression ratio up to a critical value of 13:1. Above this value, little increase in brake thermal efficiency could be obtained [16]. So the highest values of power and thermal efficiency could be achieved with compression ratio between 13:1 and 15:1 and with relative air-fuel ratio (RAFR) around the stoichiometric ratio (0.95 and 1.05) [16]. Under these conditions, HC and CO emissions would be relatively low. Another way to solve low engine performance is by advancing ignition timing. Shrestha et al improved the power output with increased diluents concentrations by advancing spark timing especially when the diluent is carbon dioxide [19].

III. CONCLUSION

As the state above, Diesel engine were really have an excellent performance as in heavy duty industries. But the emissions of the diesel engine recently making a big fuss in world environmental crisis. Inject the CNG into the diesel engine were greatly improve the emissions but, it gave a bad improvement in performance. This because of the temperature inside the combustion chamber will drop continuously. In other hand, improving the diesel engine with EGR commonly will reduce the NOx emission but just slightly reduce the performance. This method were same with inject the CO_2 into the CNG-Diesel engine. Even it will slightly reduce the performance of the engine, but certainly it will come out with good emissions especially for NOx emissions.

ACKNOWLEDGMENT

Author would like to acknowledge to University technology Petronas for financial support under grant MyRA - CO_2 Rich Natural Gas Value Chain Program From Wells To Wealth: A Green Approach.

REFERENCES

[1] Natgas. History. naturalGas.org/overview/history. September 20, 2013.[Last access: 1 April 2015]
[2] CH Cheah. Compressed natural gas (CNG) vehicles (NGV) pros and cons – facts on cost, safety and performance. myWiseWife.com. June 10, 2008. [Last access : 1 April 2015].
[3] A.E Dhole, R.B Yarasu et al. Mathematical modeling for the performance and emission parameters of dual fuel diesel engine using hydrogen as secondary fuel. *Int J of Hydrogen Energy* 2014;39:12990-13001.
[4] Saravanan N, Nagarajan G. An experimental investigation of hydrogen-enriched air induction in a diesel engine system. *Int J Hydrogen Energy* 2008;33:1769-75.
[5] Saravanan N, Nagarajan G. Performance and emission studies on port injection of hydrogen with varied flow rates with diesel as an ignition source. *Appl Energy* 2010;87:2218-29.
[6] Boretti A. Advantages of the direct injection of both diesel and hydrogen in dual fuel H_2ICE. *Int J Hydrogen Energy* 2011;36:9312-7.
[7] Gomes Antunes JM, Mikalsen R, Roskilly AP. An experimental study of a direct injection compression ignition hyrogen engine. *Int. J Hydrogen Energy* 2009;34:6516-60
[8] Kraipat C,Chedtawut P, Choi G.H. performance and emisisions of a heavy duty engine fuelled with diesel and LNG Liquid Natural Gas). Energy 2013;53:52-57.
[9] Kumar S, Kwon HT, Choi KH, Lim W, Jae HC, Tak K, et al. LNG: an eco-friendly cryogenic fuel for sustainable development. *Applied energy* 2011;88:4264-73.
[10] PowarsC, Pope G. California LNG transportationfuel supply and demand assessment. Sacramento(CA): California Energy Commission; 2002 Jan. Report No.:P600-02-002F.Contract No.:500-00-002.
[11] Verbeek R, Kadijk G, van Mensch P, Wufflers C, van den Beemt B, Fraga F. Environmental and economic aspects of using LNG as a fuel for shipping in the Netherlands. Wageningen: The Dutch Maritime Innovation Programme; 2011 Mar. Report No.:TNO-RPT-2011-001166 March 2011.
[12] Chandler K, Proc K. Norcal prototype LNG truck fleet: final results[internet]: Golden (co): National Reneweble Energy Laboratory (US). Available from: www'afdc.energy.gov/pdfs/35427.pdf;2004c.
[13] Frailey M. Development of LNG-powered heavy-duty trucks in commercial hauling. Golden (co): National Renewable Energy Laboratory (US); 1998 Dec. Report No.:NREL/SR-540-25154. Contract NO.: DE-AC36-98-G0010337.
[14] Bari, S, 1996. Effect of carbon dioxide on the performance of biogas/diesel dual fuel engine. *Renewab. Energy*, 9: 1007-1010
[15] Korakianitis, T., A.M. Namasivayam and R.J Crookes, 2011. Natural-gas fueled Spark-Ignition (SI) and Compression Ignition (CI) engine performance and emissions. Prog. *Energy Combust*. Sci., 37: 89-112.
[16] Das, L., R. Gulati and P.K. Gupta, 2000. A comparative evaluation of the performance characteristic of a spark ignition engine using hydrogen and compressed natural gas as alternative fuels. *Int. J. Hydrogen Energy*, 25 : 783-793.
[17] Ibrahim, A. and S. Bari, 2009. A comparison between EGR and lean-burn strategies employed in a natural gas SI engine using a two-zone combustion model. *Energy converse. Manage*., 50: 3129-3139
[18] Hu, E., Z. Huang, B. Liu, J. Zheng and X. Gu, 2009. Experimental study on combustion characteristics of a spark ignition engine fueled with natural gas-hydrogen blend combining with EGR. *Int. J. Hydrogen Energy*, 34: 1035-1044.
[19] Shrestha, S.O.B and G.A Karim, 2001. Predicting the effects of the presence of diluents with methane on spark ignition engine performance. *Applied Therm. Engr*., 21: 3331-342

Farah Idayu Z. received the B.E. degrees in Mechaical Engineering from Universiti Tun Hussein Onn Malaysia in 2013. During 2014-present, she stayed in Centre for Automotive Research and Energy management (CAREM), in Universiti Teknologi PETRONAS to study and complete her study in Master of Science in Mechanical Engineering for under MyRa grant project 'CO_2 Rich Naturas Gas Value Chain Program From Wells to wealth: A Green Approach.