A Review of Utilization of Oxygen Enrichment with High CO_2-CNG Content for a Spark Ignition Engine

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***Abstract*— These paper represents the potential of the utilization of an enriched oxygen content on the performance and emission with CO_2- CNG content. With higher CO_2 content in an engine leads to lowers in the burning velocity and give the effect of engine performance. Enriched oxygen is one of the useful energy saving technologies for combustion systems. Usually, the presence of higher oxygen content in the intake air of an engine yield the higher power output compare with others conventional petrol and diesel. An addition, by increase the oxygen content in air intake can contribute to decrease the ignition delay and the same time can reduce the emission of carbon monoxide and hydrocarbon.**

***Index Terms*—internal combustion engine, compressed natural gas, carbon dioxide, oxygen.**

I. INTRODUCTION

In fact that the conventional fuel is depleting and emissions level of spark ignition engine for gasoline are considerably higher than fuel of gaseous. The operation of spark ignition engine on fuel lean mixture has many positive features [1]. Gasoline and diesel is one of major derivatives of petroleum which is used around the world as a fuel generate a power. Nevertheless, for the future maybe both of this fuel will become in short supply and most costly [2].

The development of fuel technology consumption for internal combustion engine in Malaysia have high demand either in power generation, industrial or transportation. Petroleum and natural gas are the main primary energy sources used in Malaysia, it can be seen at Fig. 1 that with estimated energy consumption of 40% and 36% respectively in 2012 [3].

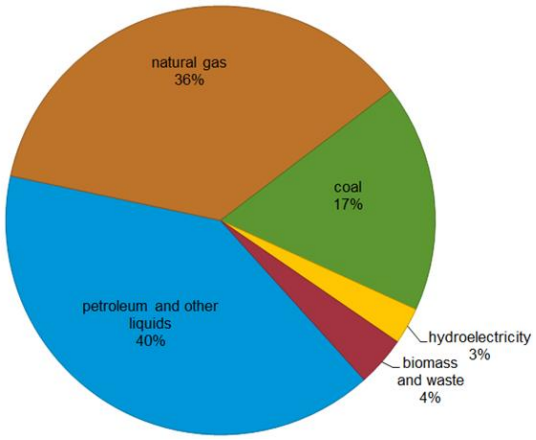

Fig. 1. Malaysia's primary energy consumption, 2012 (Sept 29, 2014 updated) [3]

Increased energy demand requires increased fuel production. Malaysia's domestic oil consumption has risen while production has fallen over the past decade, leaving smaller volumes of oil available for exports, it can be seen in Fig.2 [3].

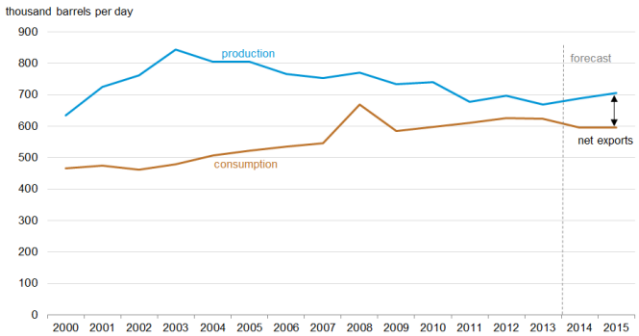

Fig. 2. Malaysia's petroleum and other liquids production and consumption, 2000 - 2015 [3].

Impending possible energy crisis in future, rising cost and toxic emissions associated with conventional petroleum fuels have caused researchers to search out and investigate the possibility of utilization of alternate clean and non-polluting

gaseous fuels for internal combustion engine .Therefore, once alternative should be defined for replace the fossil energy or the other alternative fuel is producing the economic fuel during the mixing between gaseous fuels.

Gaseous fuel like natural gas, biogas and producer gas have been responsibility as an alternative fuel to replace petrol and diesel to reduce the petroleum production [4]. Natural gas is a alternative fuel that has been used for spark ignition and compression ignition engine [5]. With used the natural gas in an internal combustion engine, it can decreased the exhaust emission and in the same time it can lowers production cost and clean burning [6]. But with used the natural gas as a fuel, the engine having a higher cyclic variation, lower power output and higher fuel consumption [7-8]. The primary component of natural gas is methane (typically, at least 75-98%), and with small percentages of other gas. A detailed typical composition of natural gas in Table 1 [6].

TABLE I
COMPOSITION AND PROPERTIES OF THE CNG USED IN MALAYSIA [6]

Component	Symbol	Volumetric (%)
Methane	CH_4	94.42
Ethane	C_2H_6	2.29
Propane	C_3H_8	0.03
Butane	C_4H_{10}	0.25
Nitrogen	N_2	0.44
Carbon dioxide	CO_2	0.57
Others	-	2.00

Spark ignition engine using natural gas can be run at higher compression ratio, thus producing higher thermal efficiency but in the same time it also increased the nitrogen oxide emission, while producing a lower unburned hydrocarbons and carbon monoxide emissions [9]. Globally as well, natural gas is increasingly becoming a favored mode of fuel. Outside the hybrid technology, it is the cleanest fuel available with carbon dioxide emissions, 20% lower than a conventional petrol vehicles [10].

Carbon dioxide is an incombustible diluents gas [11] and it characteristic is colorless, nonflammable and odorless gas [12]. Carbon dioxide has a higher specific heat capacity and this gas is a greenhouse gas in the exhaust gases from SI engine. Methane is known as the main constituent gaseous fuel that contribute to the heating value of fuel. So that, the concentration of high CO_2 in a mixture of natural gas and CO_2 can lower the heating value of the mixture. These reaction can leads to a reduction in the burning velocity which finally affects the performance of the engine [13].

Huang et al. [14] was conducted with spark ignition Ricardo engine using CNG and CO_2 at different compression ratio, speeds and equivalent ratio. The experiment found that the emission of NOx lowers. But less cylinder pressure can led to the reduction in brake torque and thermal efficiency and make HC emissions was increased.

Ayandotun et al. [15] has studied the addition of CO_2 mix with CNG in spark ignition CNG DI engine for investigate the performance and emission. The test carried out at a constant speed, maintained injection duration and full wide open throttle (WOT) with the proportion of CO_2 about 10% to 40%. The performance of brake torque will be decrease if the proportion of CO_2 is higher and the same time can reduce the heating value of the mixture when compared with pure natural gas. However, the emissions of nitrogen oxide (NOx) and carbon oxide (CO) can reduce while unburned hydrocarbon (THC) emission was higher.

Base on the review of utilization of CNG and carbon dioxide concentration, that is reason the investigation to finding the alternative gas should be keep searching and research to improve on the engine performance and emission for internal combustion engine.

II. COMBUSTION, EMISSIONS AND PERFORMANCE OF ENGINE TO EFFECT OF ENRICHED OXYGEN CONTENT

Extensive research studies have been carried out to determine the alternative fuel for spark ignition engine and other application especially for the transportations. Oxygen enrichment is a one process to increasing the proportion oxygen in air. The composition of air is 23% oxygen, 73% nitrogen and 4% other gases are available. Oxygen can produced by separating of oxygen and nitrogen from air and also same with the water with the separating by hydrogen and oxygen [16]. The oxygen can support the combustion but it not combust itself because it is not a fuel. With addition of oxygen the performance can increase and can contribute the increase of accelerate the combustion [12,17]. By increasing of oxygen readings indicate too lean an air fuel ratio; AFR must higher than 14.7 and lambda greater than 1.0 [18].

Oxygen enriched combustion is a proven method to increase available heat value or to reduce fuel consumption. In addition if more oxygen to inject to engine, the faster combustion will be happened and the emission can reduce because it will be oxidized [19-22]. From the review, many experiment get the result when increase the oxygen concentration in the combustion chamber is considerable reduction of both CO and HC emissions. Lot studies have been dedicated to oxygen enriched air intake for internal combustion engine. For example, Ng HK et al. [23] in his investigation at part loads, where the natural gas-air mixture is considering the mixture is fuel-lean. The addition oxygen can improve the combustion stability and prevents misfiring. Ggojel J et al. [24] add the oxygen content get the result lowers ignition delay, combustion duration was shortens and lower the tendency to knock.

Kajitani et al. [25] study with used single cylinder SI engine was added with oxygen enrichment concentrations of 21% to 23% to obtain performance and investigating in cylinder reaction at full load. The result is heat release lag, cycle variation and combustion period was decreased. The combustion temperature, brake thermal efficiency and engine output was increased. When concentration of oxygen about 23%, the experiment run at constant spark timing and showed the engine thermal efficiency is increase. The emission of

unburned hydrocarbon (UHC) and carbon monoxide (CO) have a reduction by 25% when optimum spark timing used with concentration of oxygen from 21% to 22%. However the NOx emission was increased.

Maxwell et al. [26] investigate effect on the performance and emission in single cylinder SI engine with fueled both petrol and CNG used oxygen enriched air. Oxygen content of the intake air was varied between 20.9% to 25%. Using with an oxygen enriched air the combustion reaction more stable leads to an increased in power output, improved thermal efficiency, reduced specific fuel consumption, increased the exhaust gas temperature and have reduction in carbon monoxide and hydrocarbon emissions when the engine is fuelled.

Amirshekari [27], investigate of oxygen enriched air for reduce the exhaust emissions in diesel engine by supplying into the inlet manifold during suction stroke. The concentration of oxygen about 21% to 27%. The effect is that oxygen enrichment leads to better combustion in less fuel consumption and the break thermal efficiency was increased. With 25% oxygen in the inlet air result in the optimum performance and emission characteristic and also get higher NOx emissions.

Rajkumar et al. [28] found the result with ignition delay period was decrease about a maximum 6% for enrich of oxygen is 28% also get an average increase of 50% in the heat release. The peak pressure was increased about 12% for maximum concentration of oxygen. The thermal efficiency and the engine specific power was increase in conducted on diesel engine.

Kuppusamy et al [29] have studied with single cylinder diesel engine for investigate the effect of enrich the oxygen level in the intake air. The amount of oxygen supplied is did not exceed 4 Litres per Minute of the intake air in order to protect engine. Kuppusamy et al.[29] and Waghmare et al.[30] said by increasing the oxygen content with the air leads to faster burn rates ability to burn more fuel at the same stoichiometry and the ability to control exhaust emissions. Added oxygen in the combustion air offers more potential for burning diesel. Oxygen enriched combustion causes significant reduction in CO emission and the same time, with the oxygen enriched combustion reduces HC emission considerably. Oxygen enriched combustion technology leads to slight increase in CO2 and NOx but this problem can be solved with Exhaust gas recirculation [29].

III. Theoretical Investigation

A. Types of Graphics

Theoretical of combustion is the ideal combustion process where fuel is burned completely. A complete combustion is burning all the carbon to carbon dioxide and hydrogen to water. If component in the exhaust gas such as C, H2, CO is not burn, the combustion process is uncompleted and not stoichiometric. Chemical formulation of the fuel was determined approximately as 0.8CH4+0.2C2H6 for the CNG fuel. The chemical reaction of the fuel with air can be seen at equation (1).[31]

$$(0.8CH_4 + 0.2C_2H_6) + Y(0.79N_2 + 0.21O_2) \rightarrow aCO_2 + bH_2O + cO_2 + dN_2 \quad (1)$$

Where by:

Natural gas by volume : 80%methane and 20% ethane
Air by volume : 79%nitrogen and 21% oxygen

In the lean burn natural gas engine, air fuel ratio is extremely critical. Lean burn is a good way to increase fuel efficiency and reduce the NOx emissions. Lean burn limits are dependent on combustion chamber geometry, ignition timings, ignition energy and turbulent [32].

IV. Conclusion

Base on the reviewed paper on the performance, combustion and emissions for the utilization of enriched oxygen in intake air for internal combustion engine, it can be conclude the most of the experiment show will improve the performance and can reduce the CO and HC emissions except the NOx emissions. Oxygen enrichment is one of the best method to improve the efficiency of the engine by fast to complete combustion. The uses of oxygen enrichment in spark ignition engine under different speed and concentration of oxygen and carbon dioxide in combustion process will be discuss with various parameters like a brake specific fuel consumption, brake power, NOx and CO emissions also CO2 emission. From the previous researcher, it can be seen many experiment was running in diesel engine inject with natural gas. Oxygen enrichment is combustion technology influences in increasing the cylinder pressure. This can attributed to the reduction of the ignition delay period which means the combustion start early and higher temperature gas.

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