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EMISSION CHARACTERISTICS OF HYDROGEN ENRICHMENT IN LIGHT DUTY SINGLE CYLINDER DIESEL ENGINE

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ABSTRACT

The aim of this paper is to investigate the emission of a single cylinder diesel engine when being injected with hydrogen gas. The hydrogen gas was produced by alkaline electrolyser, which has multiple separators to separates hydrogen and oxygen gas produced. The input hydrogen gas injected into the single cylinder diesel engine was altered by changing the alkaline electrolyser input voltage. The effects of the hydrogen gas injected into the diesel engine was observed by measuring the emission characteristics. The engine emission was measured in terms of carbon monoxide (CO) and also nitrogen monoxide (NO) in parts per millionth (ppm). The results shows that, as more hydrogen gas was injected, the emission of carbon monoxide (CO) decreases while Oxides of Nitrogen (NO_x) increases.

Keywords: hydrogen gas, diesel engine, emission characteristics.

1. INTRODUCTION

Diesel engine has been prime movers of industries such as agriculture, transportation and also heavy machineries for centuries. The advantages of diesel engines compared to other internal combustion engines, are lower fuel consumptions, lower unburned hydrocarbons produced and also have better energy release compared to the other type of engines [1]. Although there are many advantages regarding the diesel engine, scientists and engineers cannot neglect the effects of pollutant emits from the burning of fossil fuels by the engine. Therefore, there are many efforts and researches conducted all over the world to produce an efficient engine that has less pollutant emitted [2]. One of the methods is by using alternative fuel such as hydrogen.

Hydrogen potential are being reviewed by many researchers shows promising future as alternative fuel due to its favorable fuel like characteristics. Hydrogen itself as an element is the most lightest, abundant and renewable source in the planet [3]. Hydrogen technology is not new and was being studied as alternative energy for the past decades. Hydrogen when injected into the diesel engine has proven to reduce the overall fuel consumption of the engine ([4], [5], [6], [7], [8], [9] and [10]). Other than that was also proven that by enriching the diesel engine with hydrogen, the efficiency of the engine also exhibits increment in performance ([5], [6], [7], [9], [10], [11], and [12]). However due to combustion by compression principle of the diesel engine, Hydrogen is not suitable to be used solely as a fuel. This is due to its higher self-ignition temperature and lower octane number compared to diesel fuel which requires an ignition source for combustion to occur. Therefore Hydrogen is feasible to be used as secondary fuel in duel fuel operation method, where diesel fuel acted as the pilot fuel to start engine combustion before hydrogen can be injected into the engine [4], [5], [8], [12] and [13]).

Past studies show that when hydrogen gas is injected in a diesel engine as secondary fuel, the engine emission shows reduction in pollutant emission ([4], [5], [9], [10], [11], and [12]). An investigation was conducted to observe the performance of diesel engine direct injection with pure Hydrogen [12]. They found out that both the Oxides of Nitrogen (NO_x) and Carbon Monoxide (CO) emitted by the engine decreases as more hydrogen was injected into the engine. The same decrement trend of NO_x also can be found in [11] when they are investigating the effects of injecting pure hydrogen gas into a diesel engine at the intake port. In review paper [5] also has stated the same behavior of emission decrement of the engine when enriched by hydrogen gas.

The dangerous gaseous emission produced from the normal diesel engine is the concern of this research. Hydrogen is expected to be a safer and cleaner fuel that can be utilize as an alternative fuel. Thus the objective of this study is to investigate the effects of hydrogen enrichment in the single cylinder diesel engine by observing the changes of the diesel engine's emission characteristics. The emission will be taken from the engine exhaust pipe in terms of NO_x and CO when the engine is in normal condition and compared with when the engine is enriched by hydrogen gas.

2. METHODOLOGY

The Hydrogen source for this experiment was produced from an alkaline electrolyser system. The alkaline electrolyser consists of multiples electrodes mounted together and sandwiched between special membranes. The membranes will isolate the hydrogen and oxygen gas produced from the cell so that a nearly pure quality of hydrogen gas can be used throughout the experiment. The electrolyser solution pH was kept constant and the output hydrogen gas produced from the system was altered by altering the system's input voltage [14]. The hydrogen gas produced was injected into the single cylinder diesel engine through the air intake port of the engine. The single cylinder diesel engine used has the following specifications as stated in Table-1.

Table-1. Engine specifications.

Engine Model	AIRMAN YANMAH YX2500CX4
Max engine speed	3600 rpm
Max torque output	4.7 hp
Cont. torque output	4.2 hp
Engine type	Single cylinder, 4-stroke, direct injection

The diesel engine, as shown in Figure-1 is mounted to a dyno test rig so that the speed of the engine can be adjusted by controlling the dyno via software. There are three conditions that the engine being tested to which are, at normal condition, when injected with 250 ml/m Hydrogen and when injected with 300 ml/m Hydrogen.

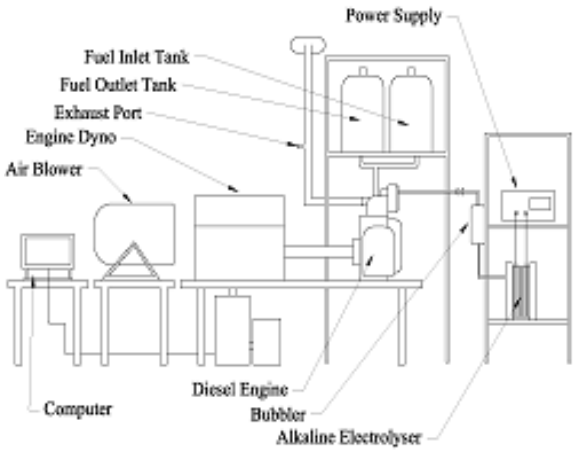

Figure-1. Schematic diagram of experimental set up.

The emission of the engine was observed and measured by using Bacharach PCA3 Combustion Analyzer which can measure CO and NO_X. All the data from experiment will be recorded, analyzed and also compared for further analysis

3. RESULTS AND DISCUSSIONS

Carbon monoxide (CO) emission

The experiment was conducted to observe the changes in emission of the engine in terms of CO emission. From the experiment, the following data was recorded as shown in Figure-2.

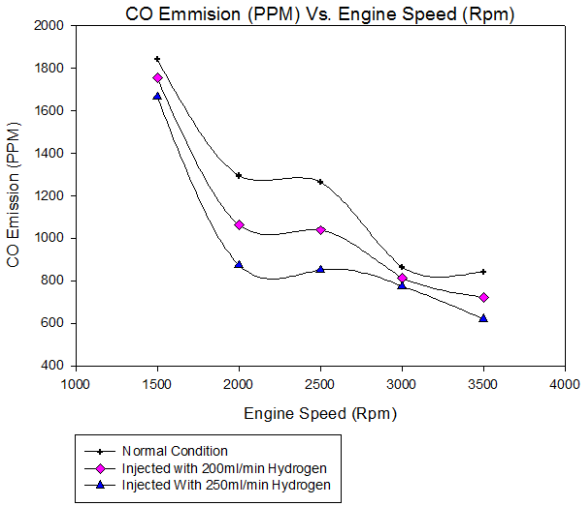

Figure-2. Variations of carbon monoxide, CO with engine speed.

From the data obtained it is clearly shown that by injecting hydrogen into the engine, there are certain trends of decrement in emission recorded. As more hydrogen was injected into the engine, less CO emitted from the engine. The lower level of CO emission is due to less fuel was burned during the dual fuel combustion process. During normal combustion, the engine combustion depending solely to the diesel fuel which has rich carbon chain structure molecule. This carbon chain molecule will transformed into other carbon based products such as CO_2 and CO after the combustion process ([9] and [10]). When the engine operates in enrichment state, the mixed fuel contains diesel that was burned with hydrogen enriched air. Hydrogen when burned do not produces any CO as its product [11]. During this state less fuel was burned thus less CO was produced.

Oxide of nitrogen (NO_X) emission

For the investigation of NO_x emission with hydrogen enrichment, the following data was recorded as shown in Figure-3.

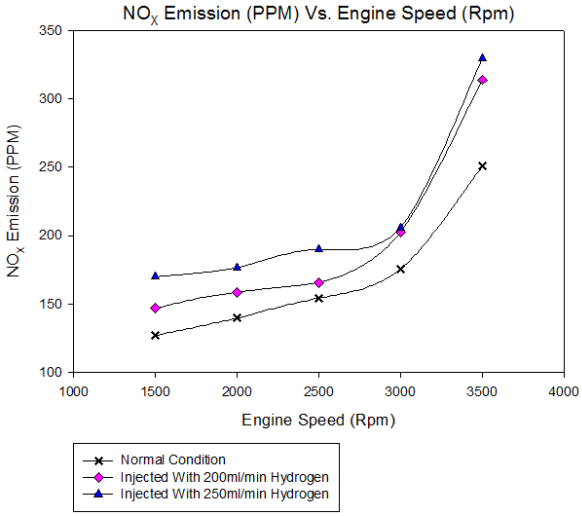

Figure-3. Variations of oxides of nitrogen NO_X with engine speed.

From the data obtained it was clearly shown that by injecting hydrogen into the diesel engine, there are certain trends of increment in emission recorded. As more hydrogen was injected into the engine, more NO_X emitted from the engine. The higher level of NO_X emission is due to the active state of nitrogen during dual fuel mode. The burning of hydrogen and fuel resulting in higher temperature and peak pressure to occur [9]. The higher temperature and pressure was causedby higher flame speed and instantaneous combustion of hydrogen during combustion process [9]. This condition will activate the nitrogen in air to combine with oxygen in air [11], thus contributed to higher formation of NO_x ([9] and [15]).

4. CONCLUSIONS

In the normal condition engine operation, the combustion process occurs when diesel fuel was burned with air inside the combustion chamber. The burning of diesel fuel will produce carbon monoxide (CO) and Oxides of Nitrogen (NO_X) as its byproducts. When the engine was in enrichment condition or when hydrogen was injected into the engine, the emission trends show a distinctive behavior. Less CO and higher NO_X was emitted by the engine. The behavior can be explained by the presence of hydrogen, which acted as secondary fuel besides the diesel fuel itself. Unlike the burning of diesel fuel, hydrogen burning is cleaner due to the facts that it will only produce water when burned with air. This resulted in less formation of CO during the combustion process. However due to hydrogen has higher flame speed and burn faster compared to diesel fuel, there might be changes to the peak pressure and temperature of the engine which provides condition for more NO_X to be formed. As conclusion, the CO emission level decreases as increasing injection of Hydrogen gas, while the NO_X emission increases as increasing injection of hydrogen gas.

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