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An Investigate on Power, Torque and Exhaust Gas Emission Variation: Effect of Hydroxy Gas Addition to Inlet Air of a SI Engine

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ABSTRACT

Hydrogen has been known as a clean and suitable fuel to replace conventional fossil fuels. One of the common hydrogen production methods is using water electrolysis process. This method produces oxygen as well as hydrogen by ratio of 1:2. The aim of this work is to investigate the effects of inlet air enrichment by adding produced hydrogen and oxygen to an internal combustion engine. For this purpose, an electrolysis system consisting of four cells have been built and the produced gas mixture was transferred to the inlet manifold of the engine via a rubber hose. The experimental results showed that addition of hydrogen and oxygen to the inlet air under full load can cause reduction in CO and hydrocarbon gas (HC) by 21% and 19% respectively, and increases power and torque by 5.5% under similar conditions.

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1. INTRODUCTION

World is facing energy and environmental pollution crisis. One of the major sources of pollutants is the exhaust gas emission from the fossil fuel combustion. This has directed research works and investigations towards engine efficiency improvement, reduction in environmental pollutions, and reduction in fossil fuel consumption by paying more attention towards clean and renewable fuels. On the same path, much research work has been directed towards effects of hydrogen addition to fossil fuels such as gasoline, diesel and natural gas, in order to improve combustion as well as exhaust gas emission. Hydrogen as a fuel without any carbon has very high flame speed and requires low energy to combust. Hence, it may combust in a lean mixture without production of any hydrocarbon gas (HC) and CO and it also can improve the thermal efficiency of the engine. Therefore, it is highly considered as a substitute to the conventional fossil fuels. The infrastructure required for for mass production, distribution and storage of hydrogen is not globally available yet, and it is still in the research and development phase. Hence, it may be considered as a mixture to improve fossil fuel combustion, until the research and development work finds a more suitable method to replace it. Andrea et al. [1] used a four cylinder V-type engine to investigate the effect of adding 2% hydrogen to the intake air. They concluded that adding hydrogen to the engine causes higher flame velocity of the combustion, and hence increase on the NO emission was observed. In their other research work [2], they investigated the effect of adding hydrogen and oxygen produced by using an electrolyser system to the intake air, and concluded that adding hydroxy gas (hydrogen and oxygen) with ratios of $\varphi<0.8$ causes increase in Torque, mean effective indicated pressure and NO emission. Chiriac et al. [3] investigated enrichment of air entering into a spark ignition engine with hydrogen and oxygen as well as OH, HO_2 and H_2O. They concluded that adding mixture of enriched hydrogen to gasoline engine, in both conditions of rich and lean mixtures, reduced HC and CO_2 which is due to reduction of incomplete combustion, and NO_X increased due to increase in adiabatic flame temperature.

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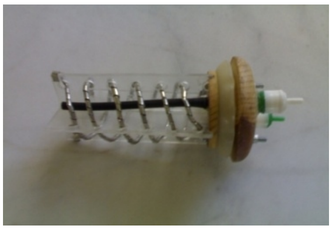


Figure 1. Shape of stainless steel electrodes

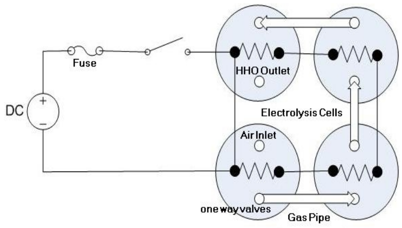


Figure 2. Electrical diagram of the electrolysis cell (electrolyte and electrodes were considered as a resistance)

Figure 3. Hydroxy gas entrance to the engine (via an unused entrance of the air intake manifold)

Variation rate of CO in the rich mixtures of fuel were non–uniform, but in the lean mixtures, CO was reduced as the amount of hydrogen increased; also, thermal brake efficiency and mean effective indicated pressure were measured to be 7.4% and 5.6% for rich mixtures and 23% and 10% for lean mixtures.

Dulger and Ozcelic [4] used water electrolyser and used the hydrogen and oxygen produced directly for various spark ignition engines. They used four different vehicles at various road traffic cycles to investigate the fuel consumption. The results show reduction of fuel consumption.

Al-rousan [5] investigated the effect of hydrogen and oxygen on a 197cc single cylinder Honda (G200) engine. Results show that by adding mixture of hydrogen and oxygen to the engine, fuel consumption reduction and engine power and thermal efficiency increase is achieved. Musmar and Al-rousan [6] on the same engine used a 2.81Lit/min capacity electrolyser system. They investigated reduction of exhaust gas emission of the engine. Results indicated a reduction of NO_X by 54%, NO by 50%, CO by 20% and HC by 40%.

Roy et al. [7] investigated performance and emissions of a supercharged engine fueled by H_2 and three other hydrogen containing gaseous fuels. Their results show that using neat H_2 at lean operation produced the highest thermal efficiency-about 13% higher than other fuels. The emission of CO and HC in neat H_2-operation was only a few ppms, and the maximum NO_x emissions was 85-90% lower than other fuels, about 200 ppm or less.

M. Mardi kolur et al. [8] investigated the effects of exhaust gas recirculation (EGR) on the emissions and performance of a Mazda B2000i SI engine. This engine was fueled separately by gasoline and two potential alternative fuels, hydrogen and ethanol. The comparison of their results when using no EGR system show that the NOx emission when using hydrogen is three and four time higher than when using gasoline or ethanol, respectively.

Birtas et al. [9] investigated effect of hydroxy gas in a tractor diesel engine, using water electrolyser for various loads and engine speeds. Their results show reduction of HC, CO, CO_2 and soot, by adding hydroxy gas up to 20% of the fuel consumption. Their NOx emission varied for various loads and engine speeds.

In this paper, effect of applying hydroxy gas using a four cells electrolyser to a spark ignition engine was investigated to determine power, torque and emission variation. The tests were conducted using a dynamometer test rig, at full load for various engine RPMs.

2. EXPERIMENTAL SETUP

In this work an electrolyser setup was built to produce hydrogen and oxygen gas. The setup consist of 4 cells, each containing uniform potassium hydroxide (KOH) solution as electrolyte and stainless steel as the electrodes as shown in Figure 1 which produces mixture of hydrogen and oxygen. The hydroxy gas produced in each cell is directed through a one way valve to a main rubber hose and again through a single one way valve and then to the air intake manifold.

The cells are linked two by two in a series – parallel manner as it can be seen in Figure 2. Experimentally, this method of connection has shown highest rate of hydroxy production. The rate of hydroxy gas production was measured experimentally using a Defender 510 gas flow meter. Hydroxy gas production was measured to be at a constant rate of 0.75 Lit/min.

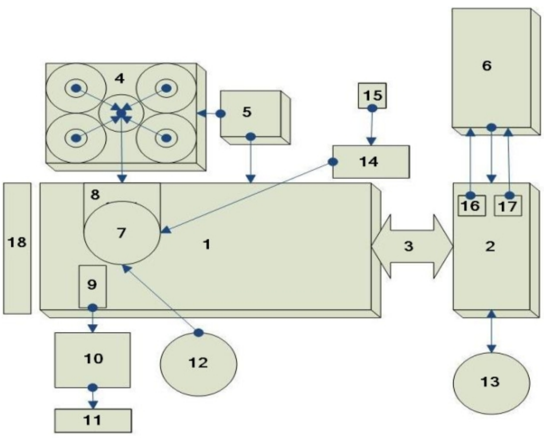
In order to investigate the effects of produced hydroxy gas on performance and exhaust gas emission of an engine, a 4 cylinders Nissan engine Z24 was used. Table 1 shows the specifications of the Z24 engine. The emitted hydroxy gas of the electrolyser system was connected to an unused entrance of the air intake manifold. Figure 3 shows the inlet of hydroxy gas to the engine. The engine was connected to an eddy – current Schenk dynamometer W130 in order to measure power and torque with and without the hydroxy gas enrichment. Schenk dynamometer specifications are given in Table 2.

TABLE 1. Engine Specification

Engine	Z24
Fuel type	Gasoline
Piston diameter	mm 89
Stroke	mm 96
Cylinder Volume	cc 2389
Max. Power	Kw/rpm 78/4800
Max. Torque	Nm/rpm 187/2400
Compression Ratio	8.3:1

TABLE 2. Dynamometer Specifications

Dynamometer	W130
Type	Eddy Current
Max. Power	kW 130
Max. Speed	rpm 10000
Max. Torque	N.m 400
Speed of Max. Torque	rpm 1100



1- Z24 Engine 2 -Dynamometer 3-Coupling 4-Electrolyser 5-Battery 6-Dynamometer control unit 7-Carburetor 8-Inlet Manifold 9-Exhaust pipe 10-Gas Analyzer 11-Printer 12- Fuel Tank 13 - Dynamometer cooling System 14-Servo motor 15-throttle valve controller 16-Speed measurement sensor 17-Load measurement Sensor 18-Radiator

Figure 4. Block diagram of the experimental setup for Dynamometer tests

A Horiba Mexa – 574GE gas analyzer was used to measure the CO, HC, CO_2 and O_2 of the engine during the test. Due to lack of appropriate apparatus, NOx emission variation could not be monitored. Since when applying hydroxy gas to the combustion chamber, hydrogen causes increase in combustion flame speed and the oxygen improves the combustion oxidation property, hence a better combustion can be achieved with higher combustion temperature, consequently higher NOx emission is expected to occur.

All tests were carried out according to ISO 3046 and DIN-70020 standards. Figure 4 shows the block diagram of the used test bed and its accessories.

3. RESULTS AND DISCUSSION

Schenck dynamometer was used to measure power and torque variations at full throttle and various RPM's. All the results were corrected considering the room temperature and atmospheric pressure. Figure 5 shows measured torque and corrected torque at full throttle for both ON and OFF condition of the electrolyser.

Overall review of Figure 5 indicates that adding hydrogen and oxygen to the combustion chamber improves the engine torque at full throttle. This is more noticeable at lower engine speeds, especially at 1000 RPM, when the electrolyser is at OFF condition (without HHO injection to the engine), no torque could be registered, and since the torque was lowered to the point that engine could not stay on. But when the hydroxy gas was applied to the combustion chamber, the torque increased and it was registered 130 Nm. Maximum torque occurred at 2000 RPM, where the hydroxy gas improvement on engine torque was increased by 2.5%. The average torque increase (without considering 1000 rpm) was 5.5% when the hydroxy gas was applied to the combustion chamber. Overall variation trend of two curves show that maximum difference occurs at lower engine speeds. This is due to the fact that the rate of hydroxy gas production is almost constant; hence the ratio of hydroxy gas to the engine fuel consumption reduces as the engine speed increases.

Figure 6 shows the power curves of the engine when the electrolyser is on both ON and OFF status. From the curves it can be seen that applying hydroxy gas to the combustion chamber of the engine improves the power output by 10% at maximum power and in overall an improvement of 5.5% (without considering 1000 rpm) is achieved.

While the tests were carried out to measure the torque and power, the exhaust emissions of the engine at various speeds and full throttle was also measured. Figure 7 shows the CO variation for both ON and OFF statues of the electrolyser.

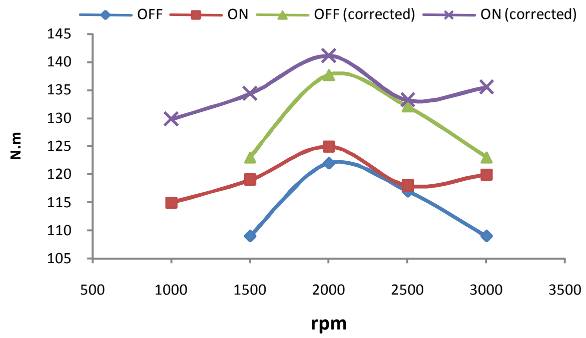


Figure 5. Measured and corrected torque at full throttle for both ON and OFF condition of the electrolyser

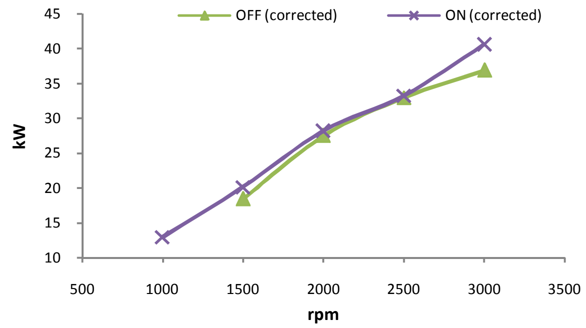


Figure 6. Power curves of the engine when the electrolyser on both ON and OFF statues

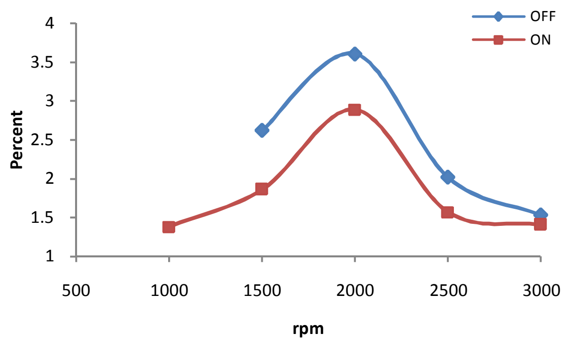


Figure 7. The CO variation for both ON and OFF statues of the electrolyser

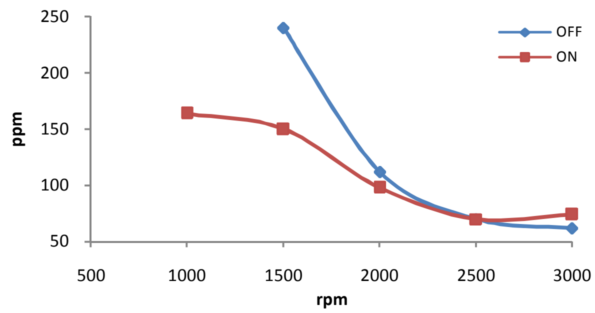


Figure 8. The HC variation for both ON and OFF statues of the electrolyser

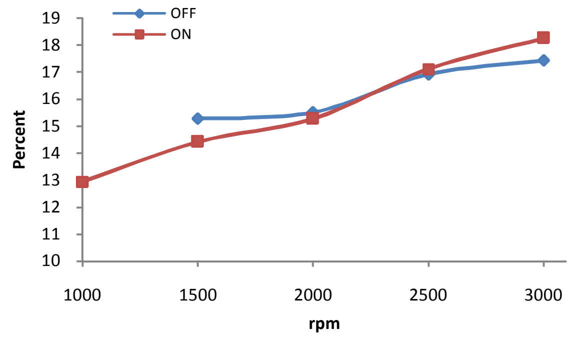


Figure 9. The CO_2 variation for both ON and OFF statues of the electrolyser

At maximum torque (2000 rpm) a peak of CO emission occurs, this could be due to opening of the second throttle valve at this engine speed, where difference of 20% is registered. But as the engine speed increases, both curves show reduction in amount of CO emission, with a difference between them, where at 3000 rpm the difference is 7.8%.

Figure 8 indicates reduction of HC for both ON and OFF conditions of the electrolyser as the engine speed increases. As it can be seen at lower engine speed, applying hydroxy gas to the engine causes reduction of HC by 37.5% at 1500 rpm and as the engine speed increases the difference between the ON and OFF curves reduces and become negligible.

Figure 9 shows increase in CO_2 as the engine speed increases and the difference between electrolyser ON and OFF condition is not extensive. Also by comparing Figures 8 and 9, a reverse pattern can be observed; therefore it can be observed that HC reduction at various engine speeds has major effect on the CO_2 emission.

4. CONCLUSION

In this work the effect of hydroxy gas addition to the air intake of an internal combustion engine has been investigated. A system consisting of four electrolyser cell was designed and applied to a Nissan Z24 engine and its effect on power, torque and exhaust gas emissions were measured using a dynamometer and gas analyzer system. All the tests were carried out according to ISO-3046 and DIN-70020 standards.

The results show that adding hydroxy gas into the engine improved both torque and power by 5.5% on average in full load condition. Without considering the 1000rpm, the emission test also indicate average reduction in CO and HC about 21% and 19% respectively and CO_2 emission diagram did not show a define trend.

Improvement in power and torque and reduction of exhaust gas emissions were mainly due to hydrogen effect in faster and complete combustion as well as the role of added oxygen for better oxidation.

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چکیده

هیدروژن به عنوان سوخت پاک و مناسب برای جایگزینی سوخت‌های فسیلی شناخته شده است. یکی از روش‌های معمول تولید هیدروژن، فرآیند الکترولیز آب است. در این روش تولید اکسیژن به هیدروژن به نسبت ۱:۲ انجام می‌شود. هدف از این پژوهش بررسی اثرات غنی سازی هوای ورودی موتور با افزودن مخلوط گاز هیدروژن و اکسیژن تولید شده توسط فرآیند الکترولیز به یک موتور احتراق داخلی می‌باشد. به همین جهت یک سیستم الکترولیز متشکل از چهار سلول الکترولیز که دو به دو به صورت موازی و سری به یکدیگر متصل شده اند ساخته شد و گاز هیدروکسی تولید شده آنها توسط شیلنگ لاستیکی به هوای ورودی موتور هدایت شد. نتایج آزمون‌های دینامومتری با استفاده از این سیستم در شرایط بار کامل بیانگر کاهش CO و HC به ترتیب ۲۱٪ و ۱۹٪ بود. توان و گشتاور با به‌کار گیری این سیستم در همان شرایط کاری، باعث افزایش میانگین ۵/۵٪ شد.

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