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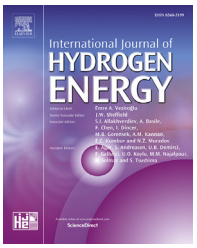

# Spark timing effect on performance of gasoline engine fueled with mixture of hydrogen–gasoline

*Ismail M.M. Elsemary, Ahmed A.A. Attia*[*], *Kairy H. Elnagar, Mahmoud S. Elsaleh*

*Combustion and Energy Technology Lab, Mechanical Engineering Department, Shoubra Faculty of Engineering, Benha University, 108 Shoubra Street, Cairo, Egypt*

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ABSTRACT

Ignition timing is heavily related to flame speed, which has great effect on SI engines performance. Due to that the flame speed for the fuel mixture that was formed by adding hydrogen to the traditional fuel was greatly changed, the ignition timing should be changed to attain suitable performance of the engine when used this mixture of fuels. The following experiments were performed to investigate the effect of ignition timing for different hydrogen percentages which mixed with gasoline fuel on a single-cylinder engine, four strokes. The tested hydrogen percentages by volume were 24%, 28%, 29%, 31%, and 49%. The analysis for engine performance was carried out at ignition timing positions (30°, 35°, 40° BTDC). The results indicated that when the ignition timing was closer to top dead center (TDC) i.e at 30° BTDC, the fuel consumption decreases and thermal engine efficiency increases. It is also noted that HC% increases and CO% were increased when spark time was more advanced for the same hydrogen concentration i.e at 40° BTDC.



## Introduction

The uncertainty of traditional sources of energy has created needs for another fuel type [1]. A new research trend to improve fuel economics and exhaust emissions reduction was conducted. Hydrogen can be used as fuel to reduced engine emissions [2]. Hydrogen as an addition to traditional fuel is a promising technique to improve gasoline engine performance especially at lean operating conditions [3]. The use of hydrogen with natural gas engine to enhance the engine performance and emissions, it found that HC, CO, $CO_2$ emissions decreased with the increase of Hydrogen percentage but NOx emissions increased [4,5].

Raviteja [6] made an experimental study on using hydrogen addition to butanol fuel on a four stroke, single cylinder engine by injecting hydrogen into the air stream. The results showed that the efficiency of engine improved, reduced delay periods, higher cylinder pressures, and improved combustion process upon hydrogen enrichment. The HC and CO emissions reduced, while the NO emissions almost doubled itself with 10% enrichment of hydrogen.

Ji [7] conducted a numerically study of the combustion phenomena in engine fueled with hydrogen–gasoline blends by using CFD. The results showed that, there was agreement between the calculated and measured values. The hydrogen addition increases the peak speed of flame compared with the original engine.

* *Corresponding author.*
E-mail addresses: i.semary@feng.bu.edu.eg (I.M.M. Elsemary), ahmed.attia@feng.bu.edu.eg (A.A.A. Attia), khairy.alnagar@feng.bu.edu.eg (K.H. Elnagar), mahmoudelsayed_20102000@yahoo.com (M.S. Elsaleh).

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**Nomenclature**

| | |
|---|---|
| BTDC | Before top dead center |
| BTE | Brake thermal efficiency |
| CAD | Crank angle degree |
| CO | Carbon monoxide |
| $CO_2$ | Carbon dioxide |
| FWOT | Full wide open throttle |
| HC | Hydrocarbon |
| HECU | Hybrid electronic control unit |
| HFSI | Hydrogen fueled spark ignition engine |
| IMEP | Indicated mean effective pressure |
| OST | Optimum spark timing |
| NOx | Nitrogen oxide |
| TDC | Top dead center |

Spark time of four cylinder engine fueled with mixture of hydrogen–methanol experimentally studied by Zhang [8]. It showed that with the spark advance increases the thermal efficiency increased and then decreased. Also the HC and CO emissions decreased when using mixture of hydrogen and traditional fuel.

Ji [9] studied effect of spark time of hybrid hydrogen–gasoline engine experimentally and showed the optimums spark timing for the maximum mean effective pressure was retarded at a specified excess air ratio. The ratio of HC and NOx emissions decreased when spark timing was retarded while there was smaller effect on CO emission with change of spark time.

The performance of engine with blend of hydrogen compressed natural gas was experimentally investigated by Lim [10] by changing the ignition timing for best torque timing. The results indicated that by retarding spark time 10° from MBT with 30% of hydrogen increased thermal efficiency and natural gas emission while decreased NOx emission compared with engine work on natural gas.

An experimental studied the ignition timing effect on engine fueled with an ethanol blended by Türköz [11] the results showed that the NOx and HC emissions increased when spark time advancing while the CO and $CO_2$ emission unaffected.

An experimentally used hydrogen in spark ignition engine to improve the performance of engine at high and low speed and load conditions by control injection time of gasoline and hydrogen. The results showed an increase in brake thermal efficiency, torque, NOx emission while there were reduction in HC and CO emission and cyclic variation with increasing the hydrogen percentage [12,13].

Syed Yousu Fuddin [14] studied the effect of ignition timing and compression ratio for engine uses hydrogen–ethanol. It found that for specified ignition time both the thermal efficiency and mean effective pressure increased with the hydrogen fraction increase.

Ma [15] studied the effect of spark time on turbocharged spark ignition engine fueled with different ratio of $H_2$-CNG blend on emissions. It showed that by increasing hydrogen ratio the brake torque decreased and thermal efficiency increased. Also HC, CO, and NOx emissions decreased with spark advance angle increased.

Akansu [16] experimentally studied effect of different mixtures ratio of hydrogen and methane on the performance of a spark ignition engine. The results showed that brake thermal efficiency, NO emissions increased while HC, CO and $CO_2$ emissions decreased with the increased in hydrogen percentage.

An experimentally study to investigate the injection of hydrogen through throttle body in natural gas engine was done by Fanhua Ma and Yu Wang [17]. Four levels of hydrogen additions were used. The study shows that the lean operation of the engines could be increased through hydrogen additions.

A study on the effects of hydrogen and methane mixture on SI engine was performed experimentally by Akansu et al. [18] using mixture 10%, 20% and 30% by volume was added. The results showed that by increased hydrogen ratio the thermal efficiency and NO emissions increase while HC, CO and $CO_2$ emission decrease.

Shi [19] studied spark timing effect on engine fueled with mixture of gasoline and hydrogen with different volume fraction of hydrogen from 0% to 10%. The results showed the brake thermal efficiency increased and then decreased with the spark advance increased while it increased with increasing of hydrogen volume fraction. The peak cylinder pressure and the maximum rate of pressure rise increased with spark advance angle increase. The NOx emissions increased and the HC and CO emissions decreased by increased the hydrogen volume fraction.

Salvi [20] conducted an experimental study performance of single cylinder engine fueled with hydrogen. The results showed an improvement of the brake thermal efficiency at higher compression ratio with reduction of residual gas fraction. The NOx emission increased with increased compression ratio and reduces the NOx emission with retarded spark timings. The spark time retarding is not a suitable for NOx emission reduction.

Jabbr [21] studied numerically the performance and emissions of engine fueled by hydrogen to study the effects of exhaust gas recirculation and ignition timing. And then obtain the best operating conditions for hydrogen engines by solving the multi-objective problem of maximizing engine power and efficiency while minimizing the NOx.

Yaodong et al. [25] study the effects of exhaust gas recirculation on an engine fueled with a gasoline and hydrogen. The results showed that, the peak cylinder pressure and the engine torque increased with a small amount of hydrogen addition. Hydrogen addition permits a higher original engine EGR rate and NOx emissions decreased also CO and HC emissions decreased with hydrogen addition.

Nitnaware et al. [26], study the effects of added hydrogen with Compressed Natural Gas on engine. The results showed that, hydrogen addition decrease in combustion duration. The MBT spark timing decreased with hydrogen addition for all fuel blends also (HC) and (CO) emissions reduced with increase in HCNG blends.

Changwei et al. [27–29], study the using hydrogen with gasoline to a rotary engine experimentally at idle and lean conditions. Results indicated that the use of hydrogen reduced engine fluctuation and fuel flow rate. Also heat addition enhancement peak temperature, pressure and heat release and HC, CO and $CO_2$ emissions reduced. The addition of hydrogen reduced coefficient of variations in peak pressure,

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