Role of Hydrogen in I.C Engines

N.V.V. Sureshwar[1],K. Gireesh[2], K.Rohith Reddy[3], I.Nagendra babu[4], K.Abhinash[5]

Abstract:

The development of combustion models, paired with the usage of biofuels, has been viewed as an effective way to minimize pollutant emissions such as CO, HC, NOx, and smoke. Indeed, homogenous Charge Compression Ignition is a novel strategy to significantly reducing NOx emissions and smoke due to lower cylinder temperature and a higher rate of homogenous air fuel mixture as compared to compression ignition engines. The experimental findings demonstrated the maximum brake thermal efficiency, despite a 4.1% decrease compared to diesel in normal mode. Hydrogen energy is a key technical pathway for achieving carbon peak and neutrality. One method of utilizing hydrogen energy is through a direct injection engine. It has the advantage of increasing thermal efficiency and reducing aberrant combustion phenomena.The impact of using hydrogen to increase fuel economy and considerably reduce exhaust emissions. The use of hydrogen in S.I. and C.I. engines has been researched.

Keywords:

1) Hydrogen.
2) Internal Combustion Engine.
3) Combustion with High Pressure Injection
4) Zero emissions.

Introduction:

Because of population growth and excessive usage of fossil fuels, demand for them has increased in the twentieth century. In 2023, 1.5 billion vehicles and trucks were on the road worldwide. By 2050, the number of autos may exceed 3-3.2 billion. The decline in fossil fuel availability has resulted in an energy (fuel) crisis. IC engines, on the other hand, will continue to dominate the transportation and power industries because of their versatility. Pollutants released by internal combustion engines have an impact on the atmosphere, causing major issues such as global warming, air pollution, acid rain, and respiratory disorders. Hydrogen offers exceptional properties as a carbon-free fuel. Hydrogen has three times the heating value of petroleum in internal combustion engines and fuel cells, and it emits far fewer toxic exhaust emissions, which are a key disadvantage of fossil fuels. The heating value of hydrogen is 4, 2.8, and 2.4 times that of coal, gasoline, and methane, respectively. In general, the use of hydrogen in internal combustion engines may be a viable low-cost method for reducing emissions. The in-cylinder gas flow parameters have a significant impact on the combustion process, fuel consumption, emissions, and engine performance.

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Description:

Vehicles are powered by two types of hydrogen-based technologies: hydrogen fuel cells (HFCs) and hydrogen-fueled internal combustion engines. The advantages of hydrogen FCVs include excellent efficiency and a lack of toxic pollutants. FCVs use electrochemical reactions to generate power from hydrogen and oxygen. Another technique of creating hydrogen is electrolysis of water, however this requires a considerable quantity of electricity, making it expensive. In this situation, the level of CO2 emissions is determined by the electrical source. Less prevalent ways for producing hydrogen include biomass gasification, biomass-derived liquid reforming, and microbial biomass conversion. However, only the solar-hydrogen and wind-hydrogen systems provide emission-free but expensive hydrogen synthesis. The ubiquitous application of hydrogen for modern energy needs has led to major investment and research in renewable hydrogen production in several nations. Alternatively, the advantages of H2ICEs include reliance on a mature industry with a large production infrastructure, the ability to offer "flex-fuel" to aid in the transitional period, which could aid in the deployment of the hydrogen infrastructure, lower hydrogen requirements compared to HFCs, ultra-low emissions, and part load efficiencies in comparison to conventionally fueled vehicles.

Hydrogen storage:

Because hydrogen has a very low density (0.089 kg/m3) at atmospheric pressure, its physical storage needs ultra-high pressure in gas bottles or extremely low temperatures in liquid.

Current uses require hydrogen to be compressed between 40 and 65 MPa. Storing hydrogen in hydrogen-dense liquid fuels has the extra benefit of being compatible and synergistic with grid storage and the global transit of renewable energy.

As a result, new methods of storing and using hydrogen in liquid fuels would bring the following two benefits for low- and zero-carbon transportation:

(1) Increases the usage of hydrogen in current engines.
(2) Improves engine performance and reduces emissions with a synthetic fuel blend through improved atomization and combustion.

The use of gaseous bubbles in liquids is an emerging method for storing hydrogen. This method has been investigated for use in aquaculture, water treatment, and biomedical engineering. Bubbles have been found to remain stable in liquid for months while having an extraordinarily high internal gas density (30-340 kg/m3). The tank material must have both strong chemical bonding and closed atomic bonds. The material also requires enough free atomic packing to allow for the rapid diffusion of gaseous hydrogen between the surface and the bulk. The material must have an adequate thermal conductivity to decompose due to the heat emitted during hydration.

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Hydrogen Injection:

Hydrogen can be introduced into the combustion chamber using two methods:

1. Port Injection System:

In an intake port injection system, both air and fuel enter the combustion chamber during the intake stroke, but they are not combined in the intake manifold. In this technique, the system is built so that the intake manifold has no combustible mixture, preventing undesired combustion phenomena and air induction prior to fuel delivery. It produces a pre-cooling action, which prevents pre-ignition. Sources that potentially exist on the surface. It also helps to quench, or at least dilute, any hot residual combustion products that may be present in the compression region around TDC. The constant volume injection (CVI) method uses a mechanical cam-operated device to time the injection of hydrogen into each cylinder. The CVI block is depicted on the far right of the photo, with four gasoline lines emerging on the left side of the block.

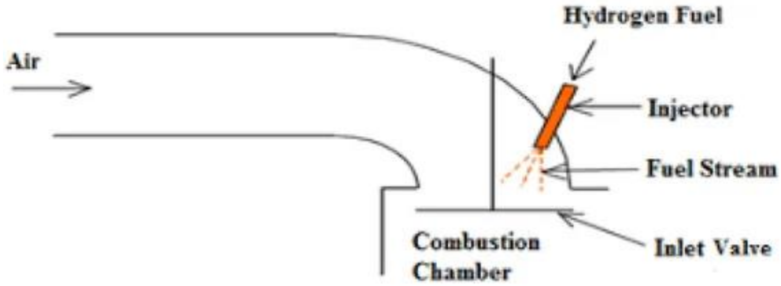


Figure 1: Port Injection System (Source: Google)

2. Direct injection System:

Direct cylinder injection of hydrogen into the combustion chamber provides all of the advantages of late injection, as typified by manifold injection. Furthermore, the mechanism allows for fuel flow after the intake valve is closed, which effectively eliminates the chance of backfiring. While direct injection eliminates pre-ignition in the intake manifold, it does not necessarily preclude pre-ignition in the combustion chamber. Furthermore, due to the shorter mixing period of air and fuel in a direct injection engine, the air/fuel mixture may be non-homogeneous. Studies have suggested that this can result in higher NOx emissions than non-direct injection systems. Direct injection systems demand more fuel rail pressure than other methods.

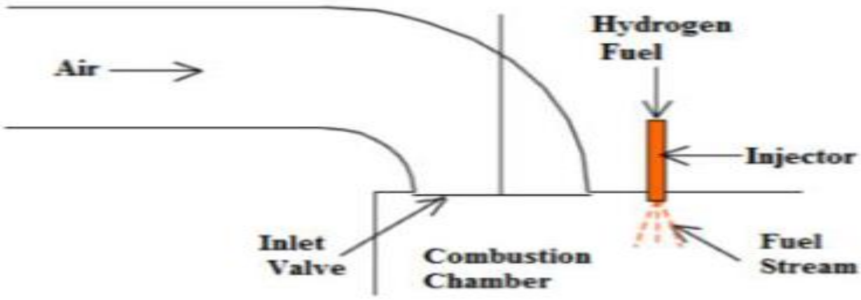


Figure 2: DirectInjection System (Source: Google)

Knocking:

Knocking is described as the auto-ignition of the hydrogen-air end-gas ahead of the flame front caused by the spark. This is followed by a quick release of the remaining energy, which produces high-amplitude pressure waves often known as engine knock. The magnitude of the pressure waves produced by high engine knock can cause engine damage due to increased mechanical and thermal stresses. An engine's knocking tendency is determined by both its design and the parameters of the air-fuel mixture. Knocking is less likely in hydrogen than in petrol or diesel because of its high auto-ignition, ignition latency, and flame speed features.

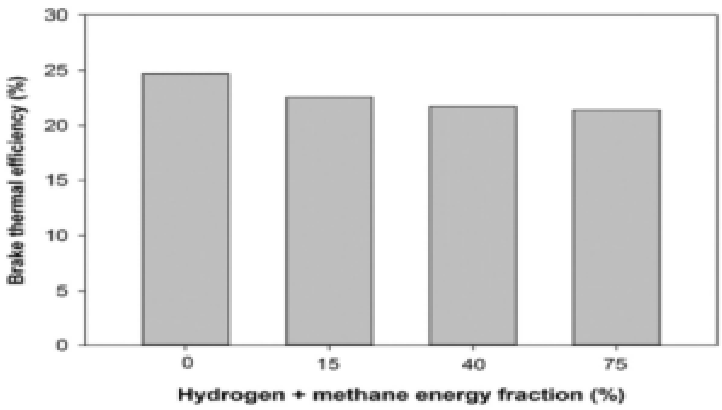
The following are the impacts of knock-on engine performance:

• Poor engine performance and potential damage to engine components.
• Improved heat transfer to the cylinder wall.
•Extremely high cylinder pressure and temperature, as well as increased emissions.

Break Thermal Efficiency:

Because hydrogen is highly combustible, its complete combustion generates an increase in cylinder pressure. The thermal efficiency of the brake system diminishes when the piston position changes. It is 24.7%, 22.5%, 21.7%, and 21.4%, with 0%, 15%, 40%, and 75% hydrogen addition, respectively. The heat flow of hydrogen exceeds that of other conventional fuels. The thermal loss increases with the addition of hydrogen.

Figure 3: Effect of hydrogen addition on brake thermal efficiency. Ref. [Yasin Karagoz, 2015]



Engine out Emissions and After Treatment:

One important difficulty with H2 combustion in IC engines is the formation of NOx pollutants as a result of lean combustion. To achieve zero-impact emissions, NOx must be eliminated from exhaust gas using an effective catalytic conversion process in a dedicated after-treatment system. One alternative is to use an SCR after-treatment system that injects urea (CO (NH2) to create ammonia (NH3). The disadvantage would be the production of CO2 emissions as a byproduct of the urea conversion reaction, which is obviously undesirable, given that the H2 engine should not emit any CO2. As an alternative, H2 can be used directly as a reducing agent to reduce NOx into N2 and H2O. Selective catalytic reduction can be performed on active catalytic substrates loaded and supported by Al2O3 and SiO2, which have been shown to be suitable in the low temperature range found in hydrogen-fueled engines operating in stoichiometric circumstances. However, in some situations, adding water vapor can improve the catalytic processes in terms of NO.

Advantages of hydrogen as fuel in IC engine:

1. Renewable energy.
2.Simple production - Hydrogen can be produced by several chemical processes, such as electrolysis of water.
3. Reduce dependence on fossil fuels.
4. High energy content per liter (only when held in liquid form).
5. There is essentially no physical delay with fuel.
6. Effective load response.
7. Ensures clean fuel combustion with reduced emissions.
8. Because there is no carbon in the fuel, the exhaust gas will not contain carbon monoxide or hydrocarbons.
9. Even gasoline loss to the environment is not considered pollution.

Disadvantages of hydrogen as a fuel in IC engine:

1. Difficult to store. To store hydrogen in a gas phase, bulk fuel storage pressure vessels are necessary.
2. If hydrogen was stored as a cryogenic liquid, it would be kept at high pressure and low temperatures.
3. Difficulty fueling and high risk of detonations.

Conclusion:

According to research and journal articles, hydrogen has a variety of applications. Many journals have suggested experiments, but few have been conducted. Based on these studies, we concluded that if hydrogen was delivered directly into the combustion chamber using the Direct Injection method, we could achieve 70-75% of the engine's efficiency without requiring much fuel. It also has the potential to remove 95% of carbon emissions and other hazardous gasses produced during combustion.

Overall, the H2 IC engines will provide a dependable, long-lasting, and cost-effective solution based on existing technology, facilitating a rapid transition to carbon-free mobility. The low total cost of ownership, particularly in heavy-duty applications, as well as its minimal reliance on scarce and expensive elements such as rare earth metals, make this technology appealing and practical in various application domains.

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