Use of Hydrogen as Energy Source: A Literature Review

Luiz Sampaio Athayde Neto[1]*, Leonardo Reis de Souza[2], Pedro Bancillon Ventin Muniz[3], Júlio César Chaves Câmara[4]

[1]Undergraduate in Automotive Engineering, SENAI CIMATEC University Center; [2]Undergraduate in Automotive Engineering, SENAI CIMATEC University Center; [3]Master in Industry Engineering, UFBA/ SENAI CIMATEC University Center; [4]Doctor in Computational Modeling, SENAI CIMATEC University Center; Salvador, Bahia, Brazil

Hydrogen is a promising alternative to meet the world's energy demand, presenting many uses. Fuel cells are the most well-known use in automobiles. But Synthetic fuels is also an promissing alternative. Studies have shown the use of hydrogen as a fuel additive in internal combustion engines. This article aims to present a review of how hydrogen is used as a fuel source, as a replacement option for fossil fuels, reducing the environmental impact and CO_2 emissions. Finally, in this review, some advantages and disadvantages will be preseted.
Keywords: Hydrogen. Fuel Cell. Synthetic Fuel. Additive. Energy.

Introduction

Reducing the environmental impacts caused by global warming, acid rain, and the degradation of the ozone layer from the burning of fossil fuels. There are researches on courses to find alternatives according to each process [1].

Hydrogen is one of the most common elements on our planet. To several studies, Hydrogen is promised to be the energy source of the future, presenting itself as a potential substitute for fossil fuels in transportation [2]. When used as an energy source, it has the potential to reduce CO_2 emissions. H_2 is used in fuel cells to produce electricity [3]. When it comes to environmental benefits, it can drastically reduce CO_2 emissions because of its main product, which is water.

This research review presents the advantages and disadvantages of using hydrogen as an energy source, considering the differences between hydrogen-powered engines and engines powered with other fuels. Considering positive aspects of the use of hydrogen, such as low environmental impact; energy potential; the need to develop renewable and clean energy sources.

Received on 17 December 2021; revised 26 February 2022.
Address for correspondence: Luiz Sampaio Athayde Neto. Av. Orlando Gomes, 1845 - Piatã, Salvador - BA- Brazil. Zipcode: 41650-010. E-mail: luizsampaioathaydeneto@outlook.com.

J Bioeng. Tech. Health 2022;5(1):60-64.

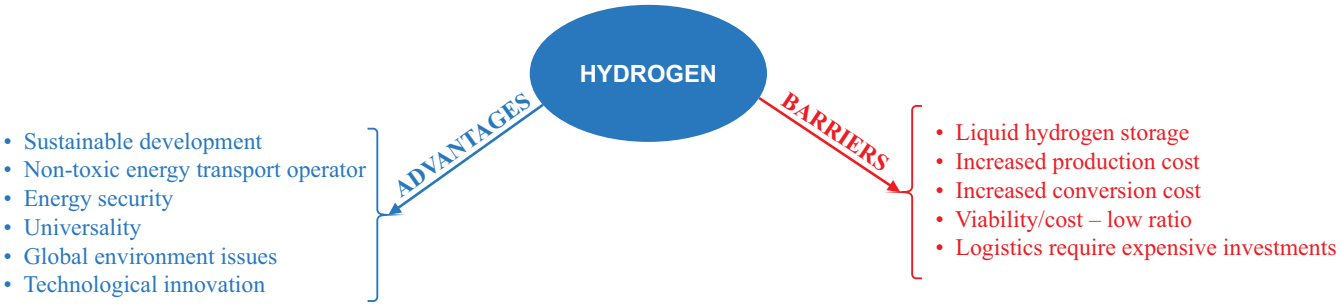
Hydrogen as Energy Source

Hydrogen Fuel Cell

Hydrogen is considered one of the cleanest energy sources if it comes from renewable sources [4]. It is one of the few renewable sources with commercial application and can be obtained from many sources [2]. In fuel cell applications, hydrogen can reach an efficiency of up to 60%. Condensation of Hydrogen happens at -252.77°C, specific weight of 71 g/L. The result is one of the highest energy densities per unit of mass, compared to other fuels. But there are some disadvantages, such as the difficulty of obtaining liquid hydrogen and its high cost of processing [4]. Figure 1 shows the diagram in which it is possible to identify the differences between disadvantages and advantages.

Fuel cells started to be studied in the 19th century. However, its first application happened with NASA between 1960 and 1970 in spacecraft [4]. In recent years there has been an increase in the use of fuel cells, in several areas in the search for efficiency, sustainable energy, and emission reduction [2]. Fuel cells differ from batteries because they work while being powered by fuel. Hydrogen is converted into a product based on hydrogen and energy that can be electricity or heat. Manoharan and colleagues (2019) explained that pressurized tanks are needed to store hydrogen in a fuel cell vehicle. It needs to be resistant because

Figure 1. Advantages and disadvantages of hydrogen.



Source: Felseghi and colleagues(2019) [4].

of safety reasons. Compressed hydrogen is under a pressure of 34 MPa, with a mass of 32.5 kg at a volume of 186 L. this condition is suitable for a 500 km range. It is also possible to liquify hydrogen in a cryogenic liquid state. It happens at a temperature of -259.2 °C. its density is not that high, 1 L of hydrogen weighs $71.37*10^{-3}$ kg. However, maintaining hydrogen in a liquid state is extremely difficult. Also, liquid Hydrogen is explosive in contact with some gases.

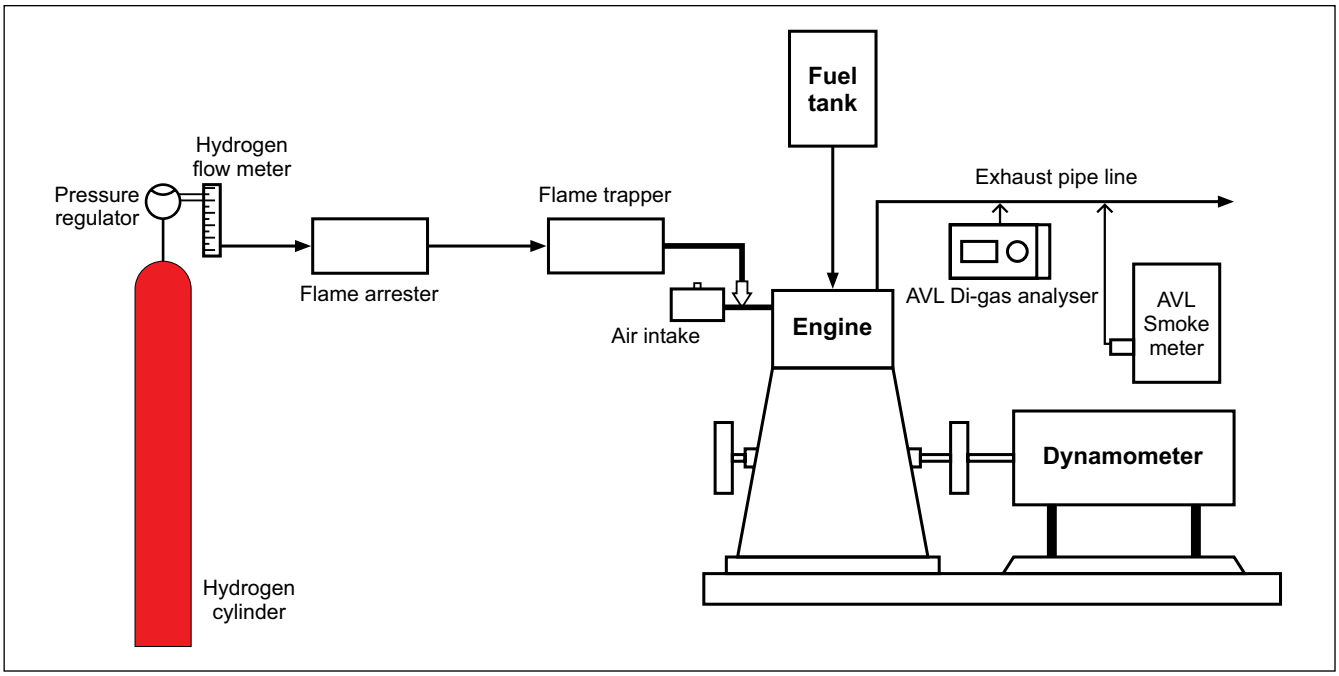
Use of Hydrogen in Internal Combustion Engines

Hydrogen, diesel, and biodiesel mixtures have been studied by several researchers. The results showed many advantages like the absence of carbon in its molecules, calorific power compared to pure diesel, and the reduction in the emission of unfriendly gases to the environment when used in compression ignition engines). Kanth and colleagues (2021) evaluated the use of hydrogen in a mixture of rice biodiesel and biodiesel of Millettia pinnata (Karanja). The experiment (Figure 2) shows the supply of hydrogen through a pressure cylinder, which was regulated to enter the diesel engine at a pressure of 2 bar and a flow rate of 7 lpm (liters per minute). A 5.2 kW CI engine was maintained in constant rotation and variable load. The experiment results demonstrated a reduction in the specific consumption of fuel, CO and HC exhausted by the engine due to better combustion from the propagation of flame caused by hydrogen [5]. However, due to higher pressure and temperatures in combustion, the indices of NOx were slightly increased.

Mohamed and colleagues (2013) conducted an experiment involving the use of hydrogen-fueled as an additive in a CI engine. Their results showed that there was an increase in thermal efficiency and a reduction in NO rates, but there was an increase in smoke emission [6]. Karagöz and colleagues (2015) evaluated the use of hydrogen intake through the air intake system pipe of a CI engine. Hydrogen was stored in a high-pressure gas cylinder (200 bar) and was injected into the engine through a pressure regulator valve (4 bar). The system also had a flame-cutting valve for safety reasons and a flow meter. Hydrogen injection occurred through an electronically controlled valve. The details of instrumentation in the hydrogen cylinder are represented in Figure 3.

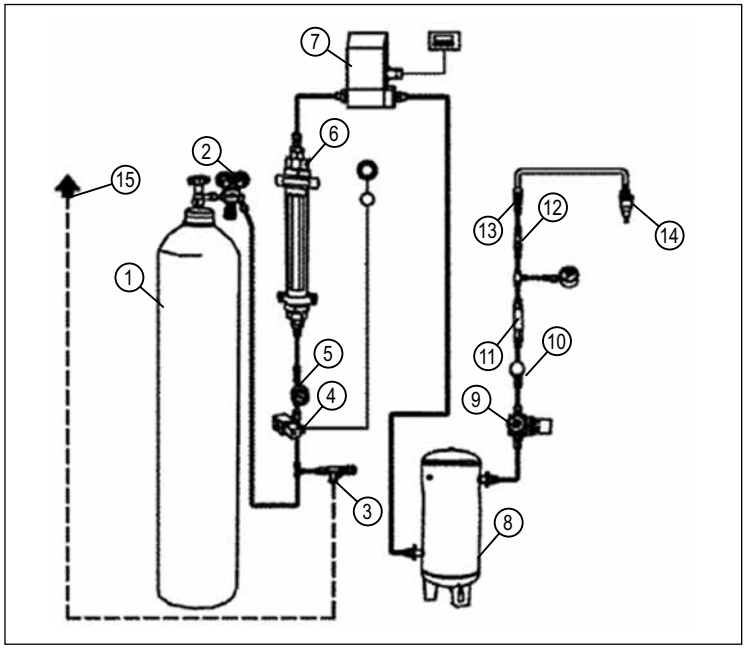
During the experiment, the engine rotation was kept constant at 1100 RPM while the load was varied (40%, 60%, 75%, and 100%). Hydrogen was injected by 30% of the total energy of the diesel and hydrogen mixture. The addition of hydrogen provided a reduction in CO emissions for all tested loads. The lower ignition delay of the H_2 is responsible for improving burning and increasing the pressure in the cylinder, providing more complete combustion of the mixture [7]. Other justification for the reduction of CO is the greater homogeneity caused by H_2. For all loads tested, there was an increase in HC. This phenomenon was associated with a higher amount of unburned fuel because of hydrogen injection into the engine. The

Figure 2. Experiment scheme for hydrogen and biofuels.



Source: Adapted from Kanth and colleagues 2021 [5].

Figure 3. Systematic display of the hydrogen.



Line: 1 - Hydrogen Cylinder; 2 - Pressure regulator; 3 - Exhaust valve; 4 - Shut-off valve; 5 - Needle valve; 6 - Hydrogen Rotation; 7 - Hydrogen mass flow meter; 8 - Tank; 9 - Pressure line regulator; 10 - Ball valve; 11 - Tailing valve; 12 - Flame suppressor; 13 - Quick connection; 14 - Hydrogen Injector; 15 - Discharge line.
Source: Karagöz and colleagues (2015) [7].

results of NOx emission varied according to the load testing. For all tested loads, the NOx values were reduced compared to pure diesel, except for the 100% load. The justification pointed out by Karagöz and colleagues (2015) is reported that in varied loads (40%, 60%, and 75%) the effect of H_2 dilution causes the reduction of the emitted. For the load of 100%, the increase in the peak temperature in the cylinder results in the higher formation of NOx. Pressure analysis in the cylinder indicated an increase for all tested loads due to the rapid flammability of H_2 and reduced ignition delay.

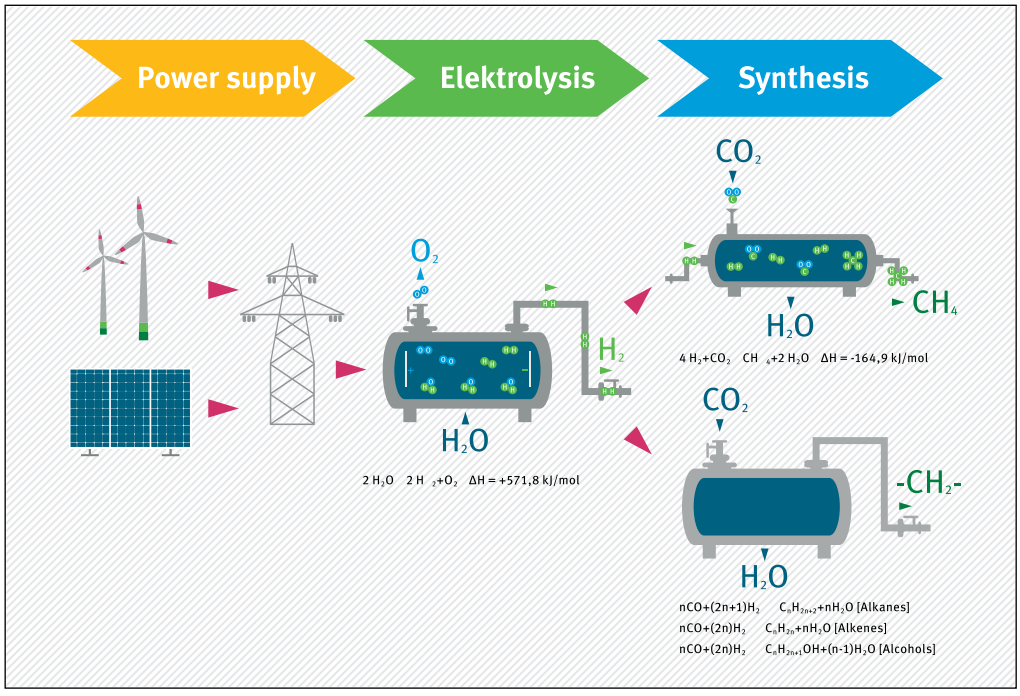
Synthetic Fuels

The goal of synthetic fuels is to create a fuel that is sustainable for heavy transport such as ships, large trucks, and some passenger cars [8]. Synthetic fuels are less efficient than electricity, which means that electric batteries are preferred in vehicles, but it is a way to reduce carbon emissions in aeronautics and the naval industry [9]. The generation of synthetic fuels begins in the same way as hydrogen is obtained for a fuel cell application. However, there is an introduction of atmospheric CO_2 used to create a larger carbon chain, such as Alcohol, Gasoline, Diesel, or other larger hydrocarbons. Figure 4 shows the process of introducing CO_2.

Conclusion

Hydrogen is one of the best alternatives for the future due to its abundance in the universe and its high specific energy. Despite its storage problems and transport difficulties, this does not invalidate it as an alternative for the future of transport. Fuel cells appear to be the most efficient method of generating energy, as the redox process is more efficient than burning hydrogen. However, both methods are being studied by several researchers with advantages and disadvantages. Another method of using hydrogen is to be used as an additive in CI engines. In this configuration, hydrogen is injected into the inlet pipe along with atmospheric air. This configuration presents reduction results for CO, HC, and other harmful

Figure 4. Principle behind a synthetic fuel.



Source: Adapted from Bracker (2017) [9].

gases, but there are still NOx emissions being produced that have variable behavior. The use of synthetic fuels is a promising alternative for the transport sector, despite its high cost.

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