USE OF HYDROGEN AS ENERGY SOURCE: A LITERATURE REVIEW

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Abstract: Hydrogen is a promising alternative to meet the world's energy demand. The most common use in automobiles has been fuel cells. However, there is a promise use in the production of synthetic fuels. Other studies have shown the use of hydrogen as a fuel additive in internal combustion engines. This article aims to present a review of the ways in which hydrogen is used as a fuel source, showing as a replacement option for fossil fuels, reducing the environmental impact and CO2 emissions.

Keywords: Hydrogen; Fuel cell; Synthetic fuel; Additive; Energy.

UMA REVISÃO SOBRE O USO DO HIDROGÊNIO COMO FONTE DE ENERGIA

Resumo: O hidrogênio é uma alternativa promissora para atender a demanda mundial de energia, apresentando diversos usos. O uso mais comum em automóveis tem sido células de combustível, mas foi visto um potencial na produção de combustíveis sintéticos. Outros estudos mostraram o uso de hidrogênio como aditivo de combustível em motores de combustão interna. Este artigo tem como objetivo apresentar uma revisão das formas como o hidrogênio é utilizado como fonte de combustível, mostrando-se como uma opção de substituição aos combustíveis fósseis, reduzindo o impacto ambiental e as emissões de CO2. Finalmente, nesta revisão, algumas vantagens e desvantagens de usar este recurso serão apresentadas.

Palavras-chave: Hidrogênio; Célula de combustível; Combustível Sintético; Aditivo; Energia.

1. INTRODUCTION

To reduce the environmental impacts caused by global warming, acid rain and the degradation of the ozone layer from the burning of fossil fuels. Research are being done to find out which alternative is the best choice according to each process [1].

Hydrogen is one of the most common elements in our planet. Through 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 an interesting potential in reducing CO_2 emissions. H_2 can still be used in fuel cells to produce electricity [3]. When it comes to environment 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 engine and engines powered with other fuels. Considering positive aspects of the use of hydrogen, such as: Low environmental impact; its energy potential; the need to develop renewable and clean energy sources.

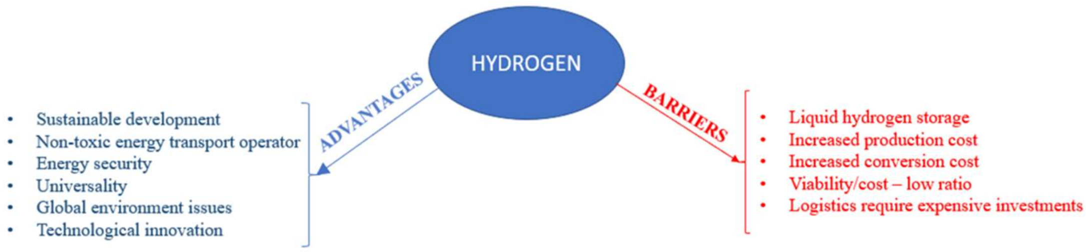
2. HYDROGEN AS ENERGY SOURCE

2.1 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 that have a large commercial application and can be obtained from a wide variety of sources [2]. In fuel cell applications, hydrogen can reach efficiency up to 60%.

Condensation of Hydrogen happens at -252.77 °C, a specific weight of 71 g/L and with this, 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.

Figure 1 - Advantages and disadvantages of Hydrogen.



Source: Felseghi et al. (2019)

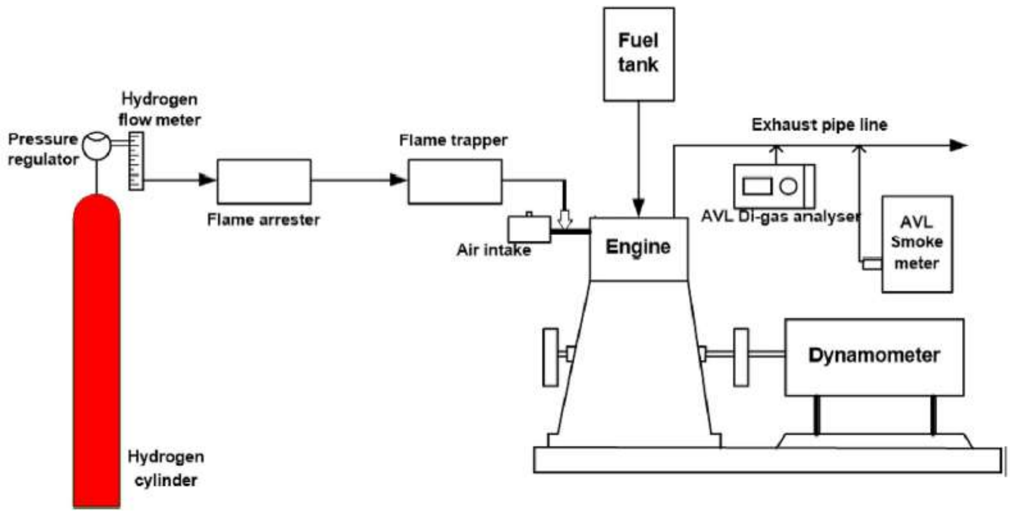
In the 19th century, Fuel cells began to be studied experimentally. However, its first application happened with NASA between 1960 and 1970 in spacecraft [4]. In recent years there has been a large increase in the use of fuel cells, in several areas with the search for efficiency, sustainable energy and emission reduction [2]. Fuel cells differ from batteries because they work while being powered by fuel. Hydrogen is converted into a product that is based on hydrogen and energy that can be electricity or heat. Manoharan et al. (2019) Pressurized tanks are needed to store hydrogen in a fuel cell vehicle. It needs to be resistant because 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 high, 1 L of Hydrogen weighs $71{,}37 \times 10^{-3}$ kg. However, to maintain hydrogen in a liquid state is extremely difficult. Also, liquid Hydrogen is explosive in contact with some gases.

2.2 Use of hydrogen in internal combustion engines

The use of hydrogen in addition to Diesel and biodiesel mixtures has been investigated by several researchers in view of its advantages such as: absence of carbon in its molecules, greater calorific power when compared to pure Diesel and the reduction in the emission of unfriendly gases to the environment, when used in compression ignition engines. Kanth et al. (2021) evaluated the use of hydrogen in a mixture of rice biodiesel and biodiesel of Millettia pinnata (Karanja). The experiment (Figure 3) 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 results of his experiment 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 the presence of hydrogen [5]. However, due to higher pressure and temperatures in combustion, the indices of NO_x were slightly increased.

Figure 2 - Experiment scheme for hydrogen and biofuels.



Source: Adapted from Kanth et al., 2021.

Mohamed et al. (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, reduction of NO rates, but there was an increase in the smoke emission [6].

Karagöz et al. (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

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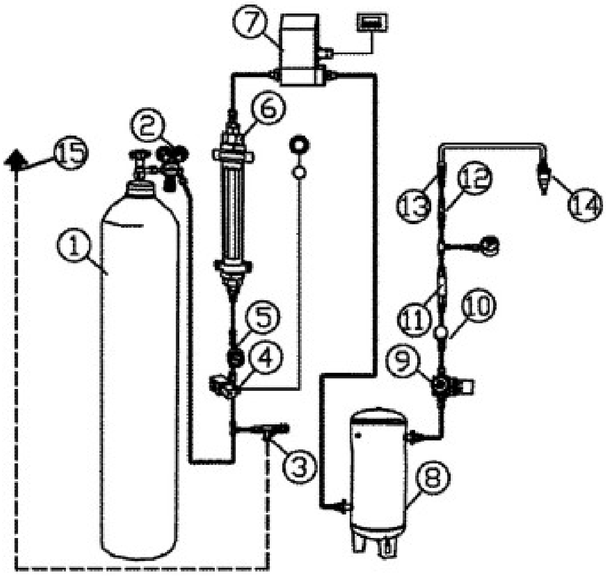
injection occurred through an electronically controlled valve. The details of instrumentation in the hydrogen cylinder are represented in Figure 4.

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 et al., 2015.

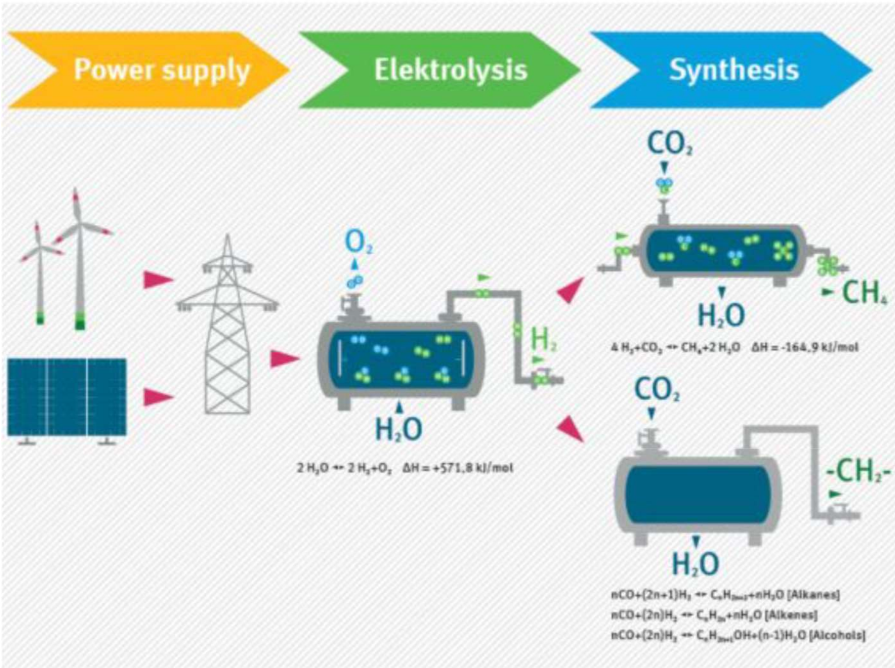
During the experiment the engine rotation was kept constant at 1100 RPM while the load was varied (40%, 60%, 75% and 100%). Hydrogen was injected by 30% in relation to the total energy of the diesel and hydrogen mixture. The addition of hydrogen provided a reduction in CO emissions for all tested loads. The lower ignition delay of the H_2 is responsible for improving burning and increasing the pressure in the cylinder, providing a more complete combustion of the mixture [7]. Another 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 results of NO_x emission varied according to the load tested. For all tested loads, the NO_x values were reduced compared to pure diesel, except the 100% load. The justification pointed out by Karagöz et al. (2015) it 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 NO_x. Pressure analysis in the cylinder indicated an increase for all tested loads due to rapid flammability of H_2 and reduced ignition delay.

2.3 Synthetic Fuels

The object 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 aviation 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. This process of introducing CO_2 is shown in Figure 5.

Figure 5 - Principle behind a Synthetic Fuel.



Source: Adapted from Hänggi (2019).

3. 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 additives 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 gases, but there are still NO_x emissions 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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