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A Comprehensive Survey on Hydrogen as a Fuel

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Abstract

Rise in global industrialization with energy demand, the need for fossil fuels are growing with each day. As a result, several countries are seeking for alternate energy sources to meet the rising need for energy. Hydrogen is indeed a high-efficiency alternative energy source with outstanding qualities. In the transportation industry, the advent of hydrogen-powered automobiles is projected to minimize fuel consumption and pollution through automobiles. Improving internal combustion engines is a straightforward method to go green. Future advancements in engine technology, as well as the use of alternative fuels, can help reduce hazardous emissions. Hydrogen remains indeed a renewable, high-efficiency, and clean energy that has the potential to safeguard engines' future. This paper provides a comprehensive survey on hydrogen by way of a fuel. The most essential avenue for the internal combustion engine to enter a new hydrogen age that can increase its durability and maximum efficiency is the advancement of elevated hydrogen energy production systems. This paper elaborates the potential of hydrogen as future fuel for variety of application as well as an agent to lowering emission from conventional engines.

Keywords: Fossil fuel; Global warming; Hydrogen fuel; Hydrogen production; Renewable energy

Introduction

Fossil fuel engines have been in use for well over century and are among the most efficient forms of internal combustion engines available. Fossil fuel-powered engines had come a very long way that since advent of diverse thermodynamic cycles in the nineteenth century, and they have the ability to go even further. Fossil-fueled engines had recently come under fire for producing significantly more pollutants in the air than other engines. The latest diesel emissions incident, in which a major automaker cheated on emissions testing on purpose, has raised even greater concern about the future and viability of fossil-fueled locomotives. Numerous papers and articles were inscribed regarding the bleak future ahead and the potential demise of diesel and gasoline engines.

Many automakers are making preparations for a future powered by hydrogen. Hydrogen could be used as a fuel in liquid fuels, where it is transformed to clean energy through an electrochemical response. Nevertheless, it's still a very expensive process in production, and it will take years before they can surpass or even replace the internal combustion engine. As a result, enhancing the performance of conventional engines and lowering harmful emissions is an obvious way to become green for immediate to mid-term ecological gain. Hydrogen as just a fuel has the potential to minimize conventional engine emissions and save diesel and gasoline engines. Over than 90% of biosphere's energy equipment is currently needful on the use of conventional fuel such as oil, natural gas, and coal, but the properties are forecast to be exhausted by conclusion of this era. Apart from this, finances of rising countries would guess the worth of the fossil fuels more unpredictable in future.

The Figure 1, Illustrates the type of fossil fuel generally used with their practical use, in which oil consumption is most utilized in vehicles, as a consequence, it is required to reduce our dependence on conventional fossil fuels as well as search for out other energy resources. In the near future, such a scenario will have an impact on the automotive industry. Another factor in contemporary decision-making is pollution. Combustion of conventional energy sources produces pollutants that may contaminate the atmosphere and contribute to climate change. Every factor are powerful motivators for substitute fuel invention and study. Amount of study done on usage of hydrogen to fuel the internal combustion based engines is extensive. The hydrogen was employed to provide a moving power in machines over two centuries ago, according to research findings [1]. Kukkonen assessed the current work on hydrogen fueled engines at the time and determined that, while hydrogen fuel seems technically possible for an engine, it would not be economical with other alternative energy sources [2].

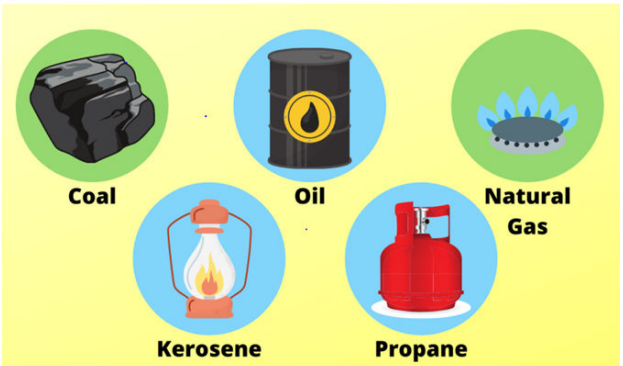

Figure 1: Illustrates the type of fossil fuel generally used with their practical use, in which oil consumption is most utilized in vehicles.

Significant breakthroughs in automobile technology, as well as the utilization of renewable energy to produce hydrogen, have positioned hydrogen as a relatively close transportation fuel in a hydrogen fuel cell. When combined with oxygen, hydrogen remains a transparent,

unscented, and zero discharge fuel. Only energy is released and water is formed when two hydrogen ions and one oxygen atom combine and react. This process can take place in two ways as a chemical response using the electrodes of the fuel cell, before as a combustible reaction using high temperature and high pressure [3]. The main physiognomies of hydrogen with different petroleum are listed in Figure 2. The high energy density of hydrogen fuel is indeed one of the key advantages. Hydrogen has one of the best energy densities of any of the regularly used internal combustion engine fuels. One kilogram of hydrogen, for example, may deliver nearly three times the energy of diesel or gasoline. The small size of hydrogen gas, on the other hand, poses serious concerns about the amount of storage space required [4].

Also, because of the small size of the fuel, hydrogen-air combination inside the combustion chambers of even an engine has a lower energy density, which might result in reduced power production. Hydrogen fuel's wide combustibility range makes it acceptable for combustion chamber in a variety of air-fuel mixes [5]. Due to full combustion within the cylinder compartments with less fuel residuals, the part surface operation could also improve the fuel efficiency of a hydrogen-fueled engine. Furthermore, it's high dispersion and gas velocity result in a quicker homogeneous combination of gas air within the cylinder, as well as enhanced combustion across a wide range. This high auto-ignition degree of the fuel, but in the other hand, needs the use of a flame trigger, including a spark or perhaps an objective of reducing temperature of supplementary fuel (Figure 3).

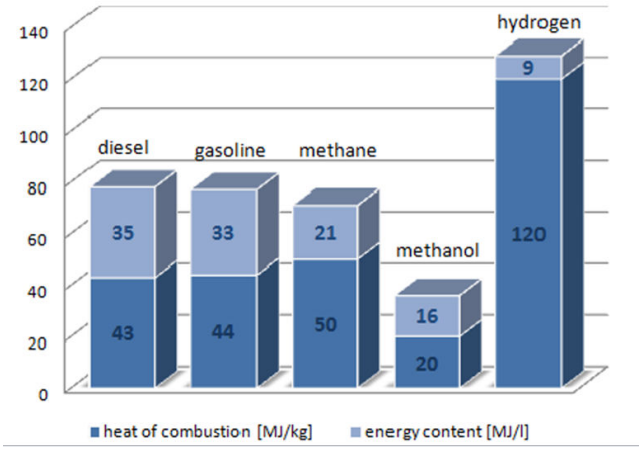

Figure 2: Illustrates the comparison of different properties of hydrogen like heat of combustion and energy content with different other fuel type.

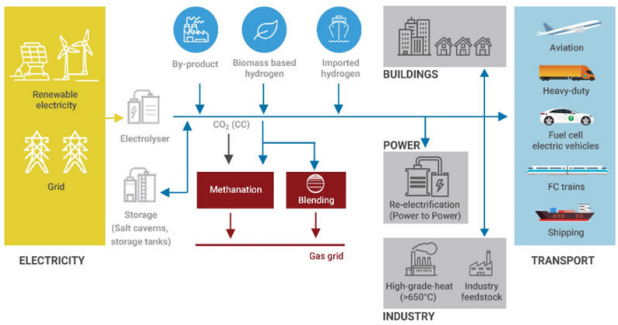

Figure 3: Illustrates the methods to produce hydrogen from different sector like electricity grid house hold and different sources.

The quantity of hydrogen found on Earth is absolutely minuscule and unpredicted due to its low density, which pushes it away first from planet's gravitational force.

As a result, hydrogen must be created by other molecules that contain it, such as crude oil, oil, charcoal, and water. Hydrogen is a form of energy that requires a source of energy, such as coal and oil or nuclear power, as well as renewable resources such as solar energy, wind energy, geothermal sources, and hydroelectric power. Hydrogen could be made in the United States from a variety of sources, reducing the country's reliance on petroleum.

As a result, hydrogen production is still seen as a high-cost, high-emission process. For the smooth transition to the new hydrogen century, the issue of whether hydrogen could be shaped abundantly and affordably from renewable sources is important. Hydrogen could be produced in a variety of ways, also with three most popular methods detailed here [6].

Formation of hydrogen using natural gas reforming

Around the globe, usual gas reformation is most common method of creating hydrogen. The technology is now mature and widely used in industry, particularly for power plant purposes.

It is the process in which natural gas is utilized for producing hydrogen gas. Most of the industries now a day using this method to produce hydrogen gas because of low cost and higher precipitation of hydrogen gas.

Formation of hydrogen by gasification

Gasification is a method of converting coal, as well as biomass including such algae, corn stalks, and industrial wastewater, into gaseous components by burning them at extreme temps. The gas is then treated through a number of chemical processes, reforming to hydrogen and carbon monoxide.

Biomass gasification produces hydrogen in a clean, nearly carbon-free manner. Gasification also includes technical process that converts any carbonaceous feedstock, such as coal, into flue gases, which is used to generate electricity.

Formation of hydrogen through electrolysis

Electrolysis is method of splitting the water into hydrogen and oxygen by means of electricity. Electrolysis is the most energy-intensive method of producing hydrogen. However, only if the electricity is generated from renewable sources is it called a clean, pollution-free process [7].

The electrolysis of water had gained a lot of interest among the various techniques of its production since it is a green and efficient chemical technology. As a result, hydrogen is a good energy vector for storing fluctuating energies. Figure 4, illustrates the methods electrolysis to produce hydrogen, in which water is used as raw product producing oxygen and hydrogen as product.

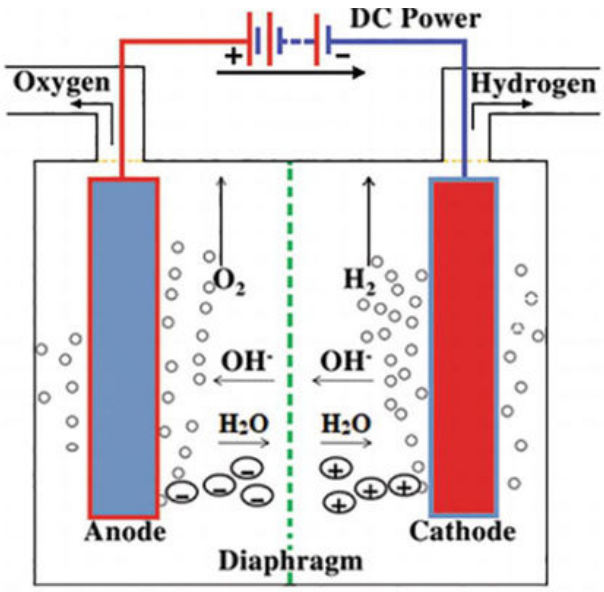

Figure 4: Illustrates the methods electrolysis to produce hydrogen, in which water is used as raw product producing oxygen and hydrogen as product.

Literature Review

Varde suggested that by excreting small amounts of vaporous hydrogen into intakes of a diesel engine naturally blown straight-injection engine, it's indeed possible to reduce diesel particles in the exhaust. They discovered that injecting modest volumes of hydrogen into the engine's inflow lowered smoke levels under part load, but that the decrease was restricted at full load condition. They discovered that injecting modest volumes of hydrogen into the engine's intake lowered smoke concentrations at part load, but that the reduction was restricted at full load condition. The best hydrogen proportion for reducing smoke was discovered to be in between 20% and 25% of amount of energy [8]. Fully utilized flow rates under low load have been shown to increase a vehicle's specific consumption, implying that even additional fuel is essential to achieve the identical power output. The hydrogen enhancement lowers the pressure distribution and delays the commencement of combustion under low loads [9]. Hydrogen does have an obvious effect on the diesel combustion chamber at high engine load circumstances, as shown by a dramatic increase in maximum in-cylinder temperature and peak flammability [10]. When compared to a clean diesel operation, this frequently outcomes in an upsurge in thermal efficiency.

The complete hydrogen enrichment of such a diesel engine was shown to have no significant influence on the fuel economy and functional engine efficiency, although it reduces its volumetric efficiency. An air turbo ramjet engine is a combined cycle power engine that combines turbojet and ramjet technology. An axial compressor compresses air after it flows through an inlet. A turbine powers that compressor, which is propelled by hot, elevated gas from a combustion process [11]. The early aspects of how a turbojet works are pretty similar, but there are a few variances. It's just that the turbo ramjet's compressor is frequently isolated from the main flow. The turbo ramjet compressor may utilize hydrogen and oxygen stored on board instead of blending air from the compressor with fuel to burn. The compressed air skips the engine's compressor and turbine portion before mixing with the rotor exhaust. Prabhu, et al. studied the impacts of water induction upon on engine's knock characteristic in order to increase the output power limit of a hydrogen based diesel dually operated-fuel engine [12]. For its high latent heat, they discovered that water could act as a powerful internal cooling, lowering the temperature of its incomplete combustion mixture [13].

Furthermore, computational models have previously been used to investigate processes running and emission production of systems that are yet too complex and expensive to implement in actual engines. Masood, et al. used the FLUENT software to simulate the combustion performance of a hydrogen-diesel multi fuel engine. The performances of a hydrogen embedded design and a fuel injection engine were compared. The model with both the approach had a 20 percent thermal efficiency in comparison with the fuel injection method, according to the major findings [14]. In this paper authors explained about hydrogen fuel used for different industries from conventional uses like internal combustion to modern uses like aerospace application. With the rise in more greenhouse gases and rising temperature importance of hydrogen as fuel is rising in recent decade that demand more attention in order to solve existing problem.

Discussion

Hydrogen fuel could be used to power liquid-fueled rockets, automobiles, trucks, railways, boats, and aero planes, as well as portable and permanent fuel cell devices that would power an automatic transmission. The difficulty of storing hydrogen either in a high pressure or a cryogenic tank is one of the issues with using hydrogen in autos. Alternative storage media are being developed, such as complicated metal hydrides. Generally speaking, batteries are preferable for automobiles and smaller vehicles, although hydrogen could be better in larger vehicles like lorries. Hydrogen fuel could also be utilized to power permanent power stations or as a heat source in place of natural gas. The multipurpose use of hydrogen as fuel in different sector is illustrated in Figure 5.

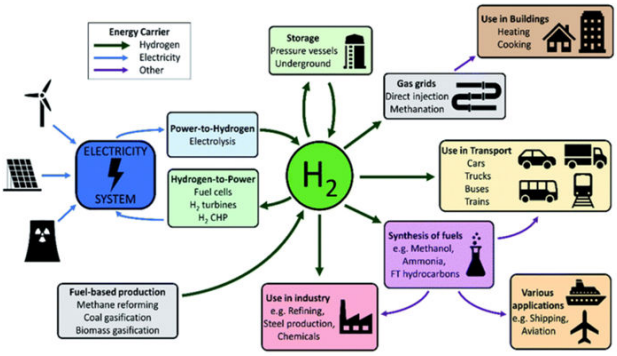

Figure 5: Illustrates the multipurpose use of hydrogen as a fuel in different sectors like automotive industries, electricity generation industries and many more.

Use of hydrogen fuel in internal combustion engines

Along with hydrogen ignition, motor vehicle combustion engines could be adapted to operate on a hydrogen-diesel mixture. Whenever the liquid fuel burns, the flame may propagate throughout the fuel combination if the proportion of flammable gas becomes larger than the threshold. Under these conditions, the high pace of reactivity of

the mixture results in increased rate of heat transfer. Unless the system is incapable of transferring this energy into useable energy, it is lost through thermal, mechanical, and vibrational causes, resulting in a knock. In comparison to natural gas, liquefied natural gas, and synthesized gas, hydrogen performs well as a secondary fuel in internal based combustion engines.

They came to the conclusion that different gaseous state fuels have distinct effects on fuel efficiency. Hydrogen as a double fuel has fewer cyclic changes than conventional fuels, resulting in lower emissions, improved efficiency, and smoother engine operation. Illustration of the line diagram of hydrogen based internal combustion engine with all the parts required for smooth operation is done in Figure 6.

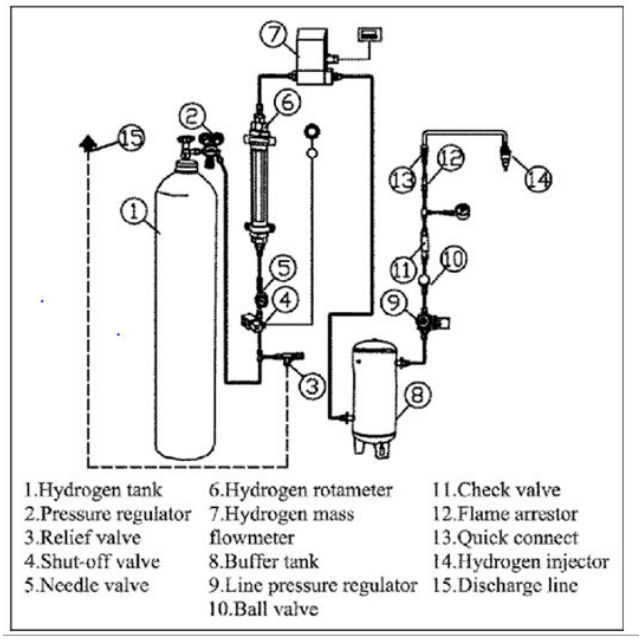

Figure 6: Illustrates the line diagram of hydrogen based internal combustion engine with all the parts required for smooth operation.

Use of hydrogen fuel in aerospace application

The Wright Field wind turbine laboratory planned this experiment throughout the fall of 1954 to see if flying an aero plane powered by liquid hydrogen was possible. The plane used for the research was a vintage twin-engine bomber with turbojet engines. The main proposal called for outfitting the plane having a hydrogen fuel system that was separate from its conventional fuel system, and also upgrading one engine to run on hydrogen and also kerosene. On its standard fuel, the flight took off and rose. One engine's propellant was converted from kerosene to hydrogen before reaching level flight at around 16,410 meters.

When hydrogen is burned in aero jet engines, a number of challenges must be addressed. In reality, in additional to systems for evaporating hydrogen that is kept in liquid form in tanks, it is important to modify the combustor to take use of the significant physical features of hydrogen over a wide range of temperatures, therefore increasing the combustion chamber's effectiveness. The entire blending of hydrogen and air is not possible in a combustor designed to burn petroleum products and equipped with a small subset of fuel injectors. Due to huge diffusive scales and quick kinetics, elevated temperatures stoichiometric strata form throughout the cylinder, resulting in high formation of no contaminants. Use of hydrogen fuel in aircraft is illustrated in Figure 7 with the culmination of solar power and other device. The core flame and nozzle take a portion of a fumes from the pre burner. The bypass fan is driven by another element that develops in a turbine. The enlarged combustion products subsequently mix with pressurized bypass air flow while entering the bypassing burner and ultimately the bypass nozzle, discharging around the main jet. During operations, the bypass fan's velocity is reduced as the bypass nozzle is gradually closed.

Figure 7: Illustrates the usage of hydrogen petroleum in an aircraft with the culmination of different connecting devices and solar power.

Conclusion

In the era of global warming and rapid growth in industrialization the fossils consumption is rapidly increasing, which in turn increases the pollution in the atmosphere as well as global warming. The global warming leads to increase in average temperature of the globe leading to uneven whether condition. The hydrogen fuel may work as savior to the global warming problem as it has low pollution emitting property. The problem with the hydrogen fuel is that the production the hydrogen fuel is much expensive as well as storing the hydrogen fuel is very tough task. Due to its low emission property there is a chance that hydrogen may play a game changing role in future so it is desirable that any problem related to production or storage of hydrogen must be removed by inventing advance technology. Although there has been conducted extensive research in the sector of hydrogen fuel but this domain is not limited and more research is demanded to explore the full potential of the hydrogen fuel.

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