- Project Title:

Fuel Cell Technology in Hydrogen Vehicles

- Introduction:

In recent times, the usage of non renewable energy, fossil fuels is increasing significantly. Due to this rise in energy demand, the usage of "Renewable energy' has gained much popularity in various fields. Fossil fuel based road transport, industrial activity and power generation contribute the highest to pollution and greenhouse gases globally. Fossil fuels cannot replenish as fast as we are burning them while their extraction and production emits planet heating greenhouse gases and pollution that threatens human health. Renewable energy is derived from natural resources that replenish in a less time without depleting nature's resources. Energy sources like sunlight, wind, rain, tides, etc. are available abundant in nature. These are not only renewable, but are also inexhaustible and they fewer greenhouse gases resulting in minimum environmental impacts. Renewable energy can also be harnessed to produce hydrogen energy. Hydrogen energy is versatile and clean energy source . It can be used for transportation, power generation and industrial processes. To use hydrogen as an energy source, it needs to be extracted and then converted into usable form. Different methods include steam methane reforming, electrolysis, biomass gasification, etc. Vehicles that run on hydrogen are called Hydrogen Fuel Cell Vehicles (HFCVs). A HFCV uses a hydrogen fuel cell to generate electricity from hydrogen and oxygen.

- Abstract:

This research paper explores the potential of Hydrogen Fuel Cell Vehicles (HFCVs) as an environmentally friendly alternative to traditional Internal Combustion Engine (ICE) vehicles and Electric Vehicles (EVs). The increasing demand for renewable energy, along with the detrimental impact of fossil fuels on the environment, has spurred interest in hydrogen energy as a clean, sustainable source for transportation. HFCVs utilize Proton Exchange Membrane Fuel Cells (PEMFCs) to convert hydrogen and oxygen into electricity, with water as the only byproduct, making them a zero-emission solution. The development of HFCVs has progressed since the 1990s, with companies like Toyota, Hyundai, and Honda playing pivotal roles in advancing this technology. Despite the environmental advantages, challenges remain, including hydrogen storage, energy efficiency, and infrastructure development. This paper highlights the innovations and improvements in HFCV technology, the ongoing research efforts to address these challenges, and the broader social and environmental benefits of adopting HFCVs. Ultimately, HFCVs represent a promising future for sustainable transportation, offering practical solutions to reduce greenhouse gas emissions and combat climate change. However, continued advancements in hydrogen storage, safety protocols, and fueling infrastructure are essential for their widespread adoption.

- Project Site:

Smart Environment friendly technology in the favour of environmental and social benefits.

- Methodology:

HFCVs in mechanical industry falls under Electric Vehicle (EV) category, however there lies some differences that sets HFCVs apart from traditional EVs. The working of HFCVs include the production of electricity by themselves in contradictory to EVs where the power comes in from a built in battery.

HFCVs convert the hydrogen in the fuel tank into electricity. HFCVs use fuel cell that produce power by converting chemical energy in the fuel i.e. hydrogen into electrical energy. This process can take place only if both the fuels an oxidants are available (operating with higher efficiency than combustion engines, fuel cell demonstrates an electric energy conversion efficiency at 60% or more with lower emissions). Since these fuel cells use hydrogen as the fuel, the only product in the power generation is water. Therefore, there are no carbon emissions. Due to advancements in technologies in HFCVs, the process of hydrogen electrification through Proton Exchange Membrane Fuel Cells (PEMFCs) is used widely in fleets of taxis, buses and vehicles. PEMFCs are well known for being efficient, reliable and ability to reduce harmful emissions. One best real world example of PEMFC vehicles is Toyota Mirai. PEMFCs operate at low temperatures (80 degree celsius) and they comprise of three main parts: anode, cathode and the proton exchange membrane. Here, the electrolyte used is perfluorosulfonic acid. Each electrode comprises of porous high surface area material and they are coated in either platinum or platinum alloy. Initially, the hydrogen gas is given to the anode where the coated platinum helps split the hydrogen gas molecules into protons and electrons. The Proton Exchange Membrane (PEM) plays a very important role by blocking the electrons and allowing the protons to pass, Therefore, the blocked electrons travel through an external circuit thus producing current. This current is used to power vehicles thereby turning the wheels and other functions of the vehicle. The protons which were allowed to pass, travel through the membrane to the cathode side. Here, the protons combine with oxygen from air. This reaction produces water and little heat as the by product.

Reaction at anode: $H2 \rightarrow (2H+) + (2e-)$

Reaction at cathode: $(1/2\ O2) + (2H+) + (2e-) \rightarrow H2O$

Net Reaction: $(H2) + (1/2\ O2) \rightarrow H2O$

- Innovations & Inventions:

The development of fuel cell technology has evolved over the years, starting in the 1970s and 1980s with initial research and early prototypes. In the 1990s, companies began working on prototype vehicles and increasing public awareness. For example, Honda introduced the FCX in 1993, and Daimler-Benz revealed their first fuel cell concept, Necar 1, in 1994. In the 2000s, technology improved significantly, and pilot programs were launched. Toyota released the FCHV-1 in 2002, while GM and Daimler collaborated on projects in 2004. BMW also made progress with the Hydrogen 7 in 2005. The 2010s saw more focus on commercializing fuel cell vehicles and building the necessary infrastructure. Toyota unveiled its FCV concept in 2013, followed by Hyundai's ix35 fuel cell in 2014 and Honda’s Clarity fuel cell in 2015. Toyota also launched the Mirai in 2015, and by 2018, there was noticeable growth in hydrogen infrastructure. In the 2020s, production and use of fuel cell technology expanded globally. New advancements came in 2020 with BMW’s iHydrogen NEXT, followed by Hyundai’s Nexo in 2021. During this time, fuel cell trucks and other commercial vehicles were also introduced. In 2022, Plug Power helped develop hydrogen fueling stations, and Toyota released its fuel cell truck, showing that hydrogen technology continues to grow and improve.

- Outcomes:

Although, HFCVs are environmental friendly and are less pollutant than traditional Internal Combustion Engine (ICE) vehicles, still they aren’t much efficient. Hydrogen’s energy content is less by volume. There are plenty of challenges while storing hydrogen gas in the fuel cells like hydrogen requires high pressure, low temperatures and the chemical reactions need to be carried out compactly. In warm, humid regions sometimes the HFCVs fueling nozzle freezes up and takes several minutes to come back to normal which is one of the major issues associated with HFCVs. Therefore, carrying out such operations in small light vehicles in a limited space becomes a tedious task. However, continous research and development is carried out continously by many automobile manufacturers around the globe in making HFCVs more efficient and reliable.

- Beneficiaries and Social Benefits:

HFCVs prove to be a better option as compared to the traditional ICE vehicles and EVs because of their environmental benefits. They are a great alternative to ICE and EVs because they can be refueled quickly and are potential for cost savings. All these pros make HFCVs an attractive option for consumers. Several more benefits include long range availability than it's alternatives providing better practicality. HFCVs do not include any combustion reactions inside their engine to generate power, that is the reason why, they are quiet and are minimal on vibrations providing a better comfortable driving experience. Overall, HFCVs are a good package with zero-emissions, sustainability and providing more efficiency and practicality.

- Conclusion:

HFCVS are the only and best alternatives to the traditional ICE vehicles and EVs because of their zero carbon emission and zero greenhouse gases emissions. With increasing technological development, the future of HFCVs is bright. Although much development and research needs to be carried out thoroughly because of the impracticality HFCVs offer due to the huge hydrogen tanks. Another safety concerns that lies among the HFCVs are about the pressure of hydrogen tanks. Lastly, boosting up the infrastructure for hydrogen filing pump stations and good after market service would make HFCVs successful and reliable option for the consumers in the coming future.

- References:

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