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Green Hydrogen Production

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ABSTRACT-

This research paper delves into the green hydrogen production process utilizing alkaline electrolysis and renewable energy sources, emphasizing the potential of green hydrogen as a clean and sustainable fuel. The study highlights the advantages of this approach, including reduced carbon emissions and minimized wastage of renewable energy. The challenges of large-scale green hydrogen production are also discussed, with an examination of the potential for implementing dimensionally stable electrodes in the electrolysis process. This paper focuses on the role of renewable energy sources. Furthermore, the study includes a comprehensive analysis of the economic viability of green hydrogen production, considering factors such as energy requirements and potential markets. The results of this research contribute to the ongoing efforts in establishing green hydrogen as a leading and sustainable energy source for various sectors, paving the way for a greener and more self-sufficient energy future.

Keywords- Alkaline Electrolyzer, Carbon Emission, Clean Fuel, DC Current, Design, Electrolyte, Energy, Green, Hydrogen, Solar Electricity, Sustainability, Water Splitting, Zero Carbon Emission

I. INTRODUCTION :

Green hydrogen is a clean and sustainable form of energy that holds promise for addressing the world's growing energy needs while mitigating climate change. It is produced through a process called electrolysis, which involves splitting water molecules (H2O) into hydrogen (H2) and oxygen (O2) using renewable electricity, typically sourced from wind, solar, or hydroelectric properties of hydrogen, power.

The term "green" in green hydrogen refers to the environmentally Cal and chemical properties of hydrogen,

Carbon emissions or other harmful pollutants. This stands in affecting the production of natural gas through a process called steam methane reforming, resulting in significant carbon emissions.

Green hydrogen has numerous potential applications across various sectors, including transportation, industry, and power generation. In transportation, it can be used to power fuel cell vehicles, offering a clean alternative to conventional internal combustion engines. In industry, it can serve as a feedstock for processes such as ammonia production or steelmaking, replacing fossil fuels and reducing emissions. Additionally, green hydrogen can be stored and utilized to balance the intermittency of renewable energy sources, thus enabling a more reliable and resilient energy system.

Although the production costs of green hydrogen have historically been higher compared to grey hydrogen, advancements in renewable energy technologies and electrolysis processes are driving down costs, making green hydrogen increasingly competitive. Governments and private companies around the world are investing in research, development, and infrastructure to scale up green hydrogen production and accelerate its adoption as a key component of the transition to a low-carbon economy.

Overall, green hydrogen represents a promising solution for decarbonizing energy systems and reducing reliance on fossil fuels, offering a pathway toward a more sustainable and environmentally friendly future. [1] [2] [3]

II. PHYSICAL AND CHEMICAL PROPERTIES OF HYDROGEN

Through this research, we find the production criteria, electrolyzer parameters, factors affecting the performance of the electrolyzer, etc. 1 kg of hydrogen is equal to 11,500 liters or 11.5 cubic meters. 1 kilogram of hydrogen is equal to 6.408 liters of liquid. 1 liter of liquid hydrogen is equal to 0.27 liters of gasoline.

The physical and chemical properties of Hydrogen,

Hydrogen is colorless, odorless, and tasteless.

Chemical Symbol=H

Physical state = Gas

Molecular weight= 1.0078

Melting point = -259.2 0C
Boiling point = -252.8 0C
Specific Gravity = 0.069
Density = 0.08988 g/l
Enthalpy = -286 KJ/MOL
Entropy = 108 KJ/MOL.K
Ignition temperature = 585 0C
Specific volume = 12.0482 ft3/lb.
Heat of combustion = -116486080 J/kg

III. CALCULATIONS AND DATA :

For 1 kg H_2 required 9-liter water.
For 0.22kg (220gm) required 2 liters of water

1) Electrolysis reaction

$$2H_2O \longrightarrow 2H_2 + O_2$$

2) Determine moles of Hydrogen produced

$$\text{Moles of } H_2 = \frac{Volume\ of\ water}{22.04}$$

For 2 liter capacity
Mole of $H_2 = \frac{2}{22.4}$ = 0.0892 mole

3) Amount of electricity required

$I = nH_2 \times F$

Where F=Faraday constant
I=0.0892 x 96,485
I=8614.73 coulomb
$I = \frac{8614.73}{3600}$ =240 amp/hr

4) Surface area of electrode

Rod dimension= 15 x 1 x 1 (l x b x h)
$A = 2\Pi rh + 2\Pi r^2$
$A = (2\Pi \times 0.5 \times 15) + (2\Pi \times (0.5)^2)$
$A = 48.69\ cm^2 = 48.69 \times 10^{-4}\ m^2$

5) Current density

$$J = \frac{I}{A} = \frac{2.4}{48.69 * 10 - 49}$$

J = 492.91 Amp/hr.

6) Actual electricity

$$I_{actual} = \frac{I}{\eta} = 2.4$$

7) Electrical Energy required to produce 1 kg of H2,

1 gm. mole H_2O = 18.015 gm.

The mole ratio of Hydrogen to the Water is,
H_2: H_20 = 1: 9
So to produce 1 kg of Hydrogen 9 kg of Water is required,
And to produce 1H2 we require 2 electronic charges, i.e 2q
The charge required to get 1 Kg H_2 is,

Q = 2q x No moles of H_2 in I kg x Avogadro Number

$Q = 2 \times 1.6 \times 10^{-19} \times (1000/2.016) \times 6.022 \times 10^{23}$

Q = 95587301.59 {Amp s/kg}

So, every molecule requires a minimum splitting voltage of
V_{split} = 1.229 V

So, the electrical energy required to produce
1 kg of Hydrogen,

Since, E = Q x V_{split}
E = 95587301.59 x 1.229 {V A sec/kg}

E = 11747679.7 Joules/kg {Watt sec /kg}

Which weight 1kg occupies volume of 0.343 m3 i.e 343liters
If 24 hours are required for 1 kg of H2, then how much energy per hour is required?

Since, 24 Hrs. = 86400 sec

$E = \frac{117476793.7\ W\ sec/kg}{86400\ sec}$

E = 1359.685 Watts/hr.kg

Material balance from reaction stoichiometry,
For 2 liter,

No of moles of $H_2O = \frac{2000}{18}$ = 111.11 mole
H_2 production will be,

$$2H_2O \longrightarrow 2H_2 + O_2$$

$$H_2O \longrightarrow H_2 + [O\text{-}]$$

Since, there is 11.11% Hydrogen present in a water molecule, so from 2 liters the maximum Hydrogen will be
Max H_2 =222.22 gm.

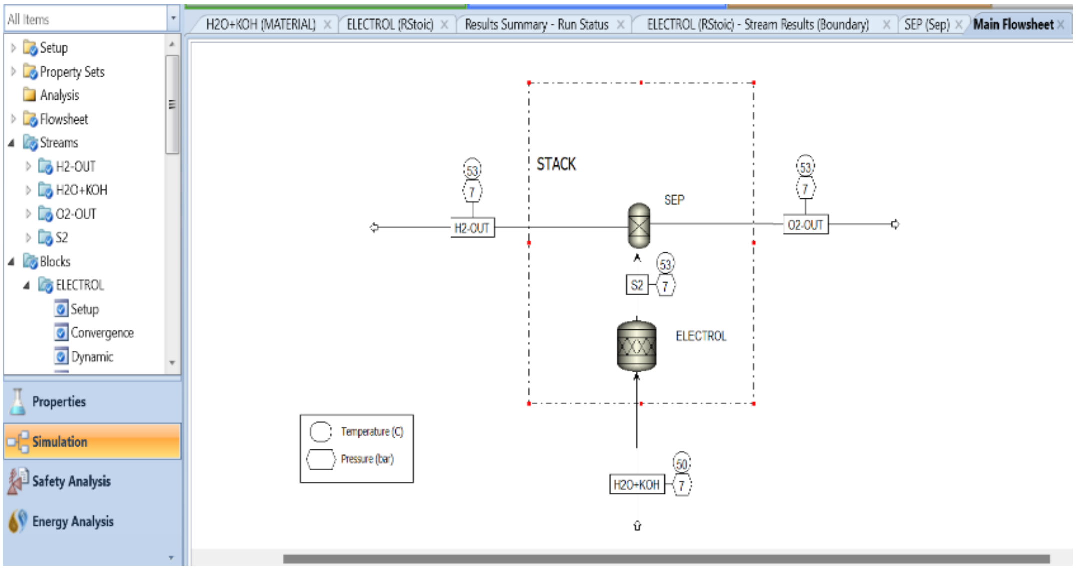
Max O2 for 2 liter
= 2000 - 222.22
=1778.88 gm. O2 per 2 kg H_2O

IV. DESIGN OF GREEN HYDROGEN PLANT USING SIMULATION SOFTWARE.

V. STORAGE FOR HYDROGEN

1) Liquid hydrogen
Volumetric hydrogen density ~ 70.8kg/m3
Hydrogen is liquefied at very low temperature
(T =252.87°C)

2) Hydrogen gas
STEPS:
1: Open the software and select the components
(Water, Hydrogen, Oxygen, Potassium-Hydroxide, H+, K+, OH-)
2: Select the Property method
Method Filter:-COMMON
Base Method:-ELECNRTL
(After completing all properties steps next to the simulation steps.)
3: Draw a main flow sheet of the plant for 1 stack.



4: Give the inlet to the system

(Temperature, Pressure, Total flow rate, Compotation of product in feed)

5: Add Chemical reaction into the Electrolyte and also fractional conversion.

6: After all the processes we get the result in the form of (Molar Fraction, Mass Fraction, Enthalpy, Density, Mole flow, Mole fraction, Mass flow, and Mass fractions.)

Storing and transporting hydrogen at 350 bar to 700 bar is the most mature method.

Volumetric hydrogen density= 39-42kg/m3

3) Liquefied or compressed synthetic natural gas

Using CO2 captured and green hydrogen, we can produce SNG.

'CO_2 Captured' +4[H2] → [CH2] +2[H2O]

Storage and delivery infrastructure for liquefied and compressed natural gas is in place and mature.

4) Synthetic fuels

$[2n+1]H_2 + nCO \rightarrow C_nH_{[2n+2]} + nH20$

If you want to use "existing storage and transportation methods", synthetic fuels are the solution.

5) Methanol [CH3OH]

Methanol can be derived from biomass or green hydrogen and captured CO2. By shifting to renewable Methanol, we can expand its use as a feedstock and fuel while meeting net carbon-neutral goals.

6) Ammonia [NH3]

Ammonia is used as feedstock, maritime fuel, and power generation. Despite its potential toxicity and corrosiveness, established safety protocols for its handling exist.

Ammonia (NH3) is produced through the Haber-Bosch process by combining hydrogen and nitrogen.

7) Liquid Organic Hydrogen Carrier (LOHC)

LOHCs can be stored at atmospheric pressure and temperature.

8) Carbon-based Porous materials

Various materials such as carbon fiber 21, nanotubes, aerogel, and activated carbon are being researched for porous hydrogen storage, with potential for commercial use.

9) Metal-organic framework [MOF]

L and PMOFs, hybrid organic-inorganic and crystalline porous materials, can be tailored for specific hydrogen storage conditions based on their structure, pore environment, and function.

10) Metal hydrides

Metal hydrides form when metal atoms react with hydrogen, and these materials are attractive for hydrogen storage. [2]

VI. CONCLUSION

"From this research, we learned that the requirements for green hydrogen production, electrolyzer basic blueprint of construction of electrolyzer, and their types, electrolytes, storage of green hydrogen, hydrogen Properties both chemical and Physical, calculations regarding the standard electrical energy required for the production of hydrogen from the water electrolysis, most importantly about the alkaline electrolyzer and its various working and design parameters."

VII. ACKNOWLEDGMENT

Firstly, we thank our Guide Prof. S.S.Patil, Prof. N. H. Shinde sir for their valuable support and, during this research paper and project, we explored lots of data that is related to Green Hydrogen production. Nowadays this is a trending topic of research in Chemical Engineering, and Sustainability so not all data is publically available, big companies like OIL, Adani Green, Reliance Industries, JSW, Shell, etc. are working on the Green hydrogen sector, from their website we got all required information, but data regarding production and design of electrolyzer is very less publically available. As this is current research topic so all the mentioned data and calculations are done by our own.

So we take a reference of the calculations provided by Abdelhalim abdelnabyn zekry (Ain Shams University).

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