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Self-Generating Hybrid Aluminum-Assisted Green Hydrogen System

Suren kumar Selvamani
Mechanical Engineer

Abstract- This work presents a hybrid aluminium-assisted hydrogen generation system utilizing waste aluminium feedstock for continuous hydrogen production through a combination of chemical reaction and electrolysis. Aluminium scrap is processed into fine particles and reacted with water in the presence of a catalyst to generate hydrogen. The system integrates a secondary electrolysis unit to extract additional hydrogen from residual water, thereby improving overall efficiency. A catalyst regeneration loop is incorporated to enable repeated use of catalytic material, while aluminium is consumed as an energy carrier and converted into aluminium oxide. The system is designed for decentralized, on-demand hydrogen generation, particularly suited for remote, off-grid, and waste-to-energy applications.

Keywords- Aluminum hydrolysis hydrogen generation, Ga-In activated aluminum hydrogen, Hybrid renewable hydrogen systems, On-demand hydrogen generation aluminum.

I. INTRODUCTION

Hydrogen is a key enabler of the global transition toward clean energy systems. However, conventional hydrogen production technologies face major limitations:

Steam Methane Reforming (SMR) produces CO_2 emissions
Electrolysis requires high electrical energy
Hydrogen storage and transport pose safety challenges
This thesis proposes an alternative approach using aluminum as a chemical energy carrier, enabling hydrogen production from low-value waste streams.

II. OBJECTIVES

The objectives of this system are:

- To develop a hydrogen generation system using aluminum waste
- To enable continuous hydrogen production
- To integrate chemical and electrochemical hydrogen generation
- To design a catalyst recovery and reuse system
- To reduce dependence on centralized hydrogen infrastructure

III. SYSTEM OVERVIEW

The system consists of the following subsystems:

- Feedstock preparation unit
- Chemical hydrogen reactor
- Gas purification and compression system
- Catalyst recovery system
- Electrolysis unit
- Material handling and control system

IV. MATERIALS AND METHODS

Feedstock Preparation
Aluminum waste (cans, scrap) is processed using:

- Pulverizer
- Fine crusher
- Result:
- Particle size: 10–100 microns

Chemical Reaction Mechanism
The primary reaction:
2Al+3H_2 O→Al_2 O_3+3H_2
Challenges:

- Aluminum oxide layer prevents reaction
- **Solution:**
- Use of catalyst to activate aluminum surface

Catalyst System
Types:

- Alkaline catalysts:
- NaOH, KOH
- Metal-based catalysts:
- Gallium, Indium alloys

Function:

- Break oxide layer

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- Enhance reaction kinetics

Reactor Design Parameters
- Temperature: 40–90°C
- Pressure: 1–10 bar
- Particle size: 10–100 µm

Reactor types:
- Stirred tank reactor
- Continuous flow reactor

Hydrogen Collection
Hydrogen is:
- Filtered
- Moisture removed
- Compressed (10–350 bar)
- Stored

Electrolysis Integration
Residual water is fed to electrolyzer:
- Voltage: 1.5–2.2 V
- Current density: 0.2–1 A/cm²

Purpose:
- Recover additional hydrogen
- Improve system efficiency

Catalyst Recovery
Methods:
- Filtration
- Sedimentation
- Chemical regeneration
- Recovered catalyst is reused.

V. PROCESS FLOW DESCRIPTION

- Aluminum scrap → Pulverizer
- Fine powder → Reactor
- Reactor + Water + Catalyst → Hydrogen generation
- Hydrogen → Filter → Compressor → Storage
- Residual slurry → Separator
- Catalyst → Recycled
- Water → Electrolyzer → Additional H_2
- Aluminum oxide → Collected

VI. RESULTS AND PERFORMANCE ANALYSIS

Hydrogen Yield

1 kg Al → ~0.11 kg H_2
9 kg Al → 1 kg H_2

Efficiency Improvements
- Catalyst increases reaction rate
- Electrolysis recovers additional hydrogen
- Hybrid system improves total yield

Cost Analysis (U.S.)
- With low-cost scrap:
- Total cost: $4–$8 per kg H_2

VII. ADVANTAGES

- Utilizes waste aluminum
- On-demand hydrogen production
- Hybrid system increases efficiency
- Scalable and modular
- Suitable for remote locations

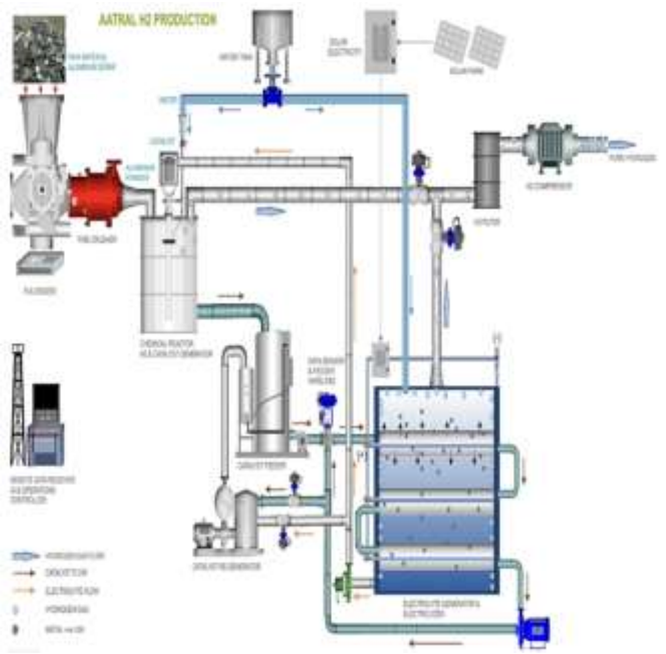
VIII. LIMITATIONS

- Aluminum is consumed (not regenerated)
- Requires preprocessing energy
- Dependent on scrap availability

IX. APPLICATIONS

- Defense and military systems
- Remote energy generation
- Industrial hydrogen supply
- Disaster relief systems
- Hydrogen fueling stations

- ❑ Zero carbon cycle process
- ❑ Waste to energy
- ❑ Innovative self-generating electrolyser design
- ❑ Continuous H2 production
- ❑ No feedstock electrolyte
- ❑ Low cost raw material
- ❑ Cost effective renewable electricity usage
- ❑ Opportunity for revenue from by products
- ❑ Low operating cost
- ❑ Low maintenance and manpower
- ❑ Easy to scale with multi-line operational facility
- ❑ Potential to operate as small on-site or large plant



X. FUTURE WORK

- Optimization of catalyst
- Integration with renewable energy
- Automation and AI-based control
- Scale-up to industrial level

XI. CONCLUSION

The proposed system demonstrates a viable approach for distributed hydrogen generation using aluminum waste. By integrating catalytic activation and electrolysis, the system achieves improved efficiency and operational flexibility. This technology presents a promising pathway toward sustainable hydrogen production in decentralized environments.

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