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Grounding by hydrogen fuel cell

Ángel Y. Gaspar Mendoza[1], M.C. Adrián de Ganzo[2,*], J. Almenar de Luz[2] J.A. González-Almeida[2]

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ABSTRACT

In this work, we will discuss fuel cells as an innovative source of energy, emphasizing their ability to directly convert the chemical energy of fuel into electricity through electrochemical processes. Unlike conventional methods, fuel cells achieve notable practical efficiencies, reaching up to 50%, and significantly reduce carbon dioxide emissions and other pollutants.
We will also emphasize the operation of fuel cells, their versatility in using various fuels, and their role in building a more sustainable energy future, with applications in vehicles and stationary generators. We will detail the manufacturing process of the fuel cell, focusing on bipolar plates, which represent more than 80% of the weight of the cell. The materials used, such as graphite and metallic compounds, are analyzed, highlighting the need to reduce costs to make fuel cells more commercially competitive.
Next, we will address the membrane electrode assembly (MEA), an expensive part of the cell that uses catalysts such as platinum. Strategies to reduce costs, such as the use of alternative polymers and optimization of catalyst dispersion, are explored.
Furthermore, a generator developed from fuel cells is presented, and procedures for grounding and hydrogen supply are detailed. The generator stands out for its efficiency, durability, and ability to operate in extreme conditions.
In general, the text provides a comprehensive overview of fuel cells, from their operation and manufacturing to their application in generators, highlighting their potential in transitioning towards a more environmentally friendly energy matrix.

1. Introduction.

Fuel cells represent an innovative frontier in energy generation, challenging traditional paradigms by converting the chemical energy of a fuel directly into electricity. Unlike conventional methods that rely on combustion, fuel cells operate electrochemically, avoiding the limitations of the Carnot cycle and achieving notable practical efficiencies, reaching up to 50%.

This revolutionary approach not only offers superior performance, but also stands out for its reduced environmental impact.

Direct conversion minimizes emissions of carbon dioxide and other pollutants, positioning fuel cells as a key alternative in the search for cleaner and more sustainable energy solutions.

Its versatility is reflected in the ability to use various fuels, with hydrogen as the main protagonist, obtained through methods such as electrolysis or hydrocarbon reforming. Oxygen, usually taken from the air, acts as an oxidant in a reaction that continuously produces electricity while fuel is supplied.

This technological advance, which operates in vehicles, stationary generators and more, represents not only an efficient alternative, but a fundamental piece in the construction of a more sustainable energy future. With applications in constant expansion, fuel cells are emerging as drivers of change in the transition towards a more environmentally friendly energy matrix.

[1]First engineer officer merchant. Master Degree Student. Universidad de La Laguna.
[2]Lecturer. Departamento de Ingeniería Civil, Náutica y Marítima. Universidad de La Laguna.
*Corresponding author: M.C. Adrián de Ganzo. E-mail Address: madriang@ull.edu.es.

2. Methodology.

2.1. Battery manufacturing processes.

The current price of polymeric fuel cells is around € 6000 / KW, but to be commercially competitive their production costs should be reduced to € 50/KW, which is the price of internal combustion engines. For this, a cost reduction in components and systems is necessary, both from the point of view of lowering the cost of the materials used and reducing the costs of the manufacturing processes; all this combined with an increase in the efficiency and reliability and durability of the system.

In this topic, the main manufacturing processes and the materials used in the different components of the battery, as well as the final assembly, will be studied. It must be remembered that, since this technology is still in development, the process of manufacturing a battery is almost artisanal, and is poorly automated. As the number of batteries to be manufactured increases, the processes will be automated, so manufacturing costs per unit will decrease.

2.2. Bipolar plates.

In the set of elements that make up a fuel cell, the weight of the stack and the current density generated depend largely on the bipolar plates.

The bipolar plates account for more than 80% of the weight of the battery and, due to the optimization of the manufacturing processes of the MEAs (Membrane Electrode Assembly) and the decrease in the catalytic charges used (Pt), the price of the bipolar plates It is increasingly important in the final price of the battery. Therefore, a reduction in the price of the materials used and in the costs of the bipolar plate manufacturing processes will significantly influence the price of the battery.

The search for a reduction in the costs of bipolar plates should not distance us from the qualities that every material that is going to be used in the manufacture of these elements must have, which are:

- Good electrical conductivity;
- Low contact resistance with the GDL
- Good thermal conductivity
- High thermal stability
- Low gas permeability.
- High resistance to corrosion
- High mechanical resistance
- Low density
- Resistant to ion dissolution

The DOE (U.S. Department of Energy) sets the objective for fuel cells used in transportation that the production costs of bipolar plates do not exceed $10/KW.

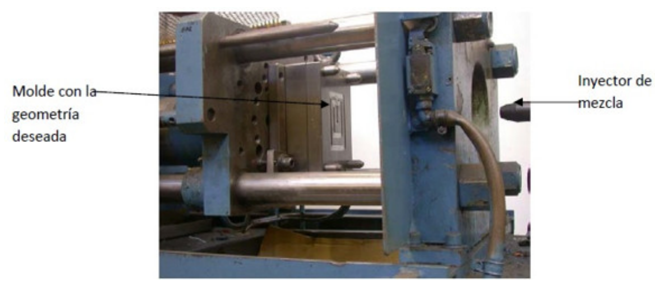
Graphite is the material that has traditionally been used to manufacture bipolar plates for PEM. Its main virtues are its chemical stability against the corrosive environment present inside the battery.

With good electrical conduction properties and great lightness, the main obstacle is its high fragility and high porosity, which generally requires the use of quite thick plates compared to metallic ones and which requires extreme precautions in their manufacture and handling by the risk of material fracture. A way to reduce

These risks consist of combining them with polymer resins (what have been called "composites") that reduce their high porosity and improve their mechanical stability with the counterpart of a decrease in their electrical conductivity.

When using pure graphite, the traditional method of manufacturing plates is by machining. Due to the high fragility of the material, this process must be carried out with extreme care. When composite materials (carbon with polymer resins) are used, the manufacturing methods used are injection molding or compression molding.

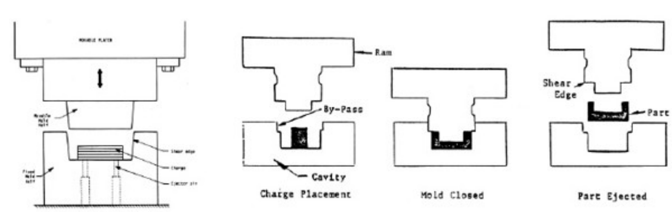
Figure 1: Injection Molding Machine.



Source: Authors.

The injection molding method consists of injecting a molten mixture of polymer and carbon into a mold under pressure, so that, when the composite material cures, the part remains in the shape of the mold. It is a method used when the volume of parts to be produced is large, although it presents dimensional precision problems, because the correct distribution of the mixture throughout the mold is complicated.

Figure 2: Compression molding process.



Source: xometry.pro.

The parts obtained by this method have good dimensional tolerances.

The channels of the bipolar plate are manufactured in the pressing of the preform. It is a process that requires more time than injection because the previous step of manufacturing the preform is necessary, but the results obtained are better.

But both graphite and composite materials are expensive materials, with expensive manufacturing processes. To reduce the costs of bipolar plates, it is necessary to use metallic materials. The advantages of using metallic materials are:

- Volume and weight reduction. Because metallic materials are non-porous and have greater resistance, it is not necessary to use plates as thick as graphite ones, which translates into a reduction in weight and volume.

- Lower costs, because the price of materials is lower and because metallic materials and manufacturing methods are cheaper.

- Great electrical and thermal conductivity.

The main disadvantage of using metallic materials is:

- Corrosion problems. Corrosion causes the formation of an oxide layer between the bipolar plate and the gas diffusion layer that increases the contact resistance between both, which decreases conductivity. In addition, metal ions can be released that degrade the polymeric membrane. For this reason, it is necessary to give anticorrosive treatments to the metal plates, even if this means reducing the conductivity and increasing the price of the material.

The metallic materials normally used in the manufacture of bipolar plates are stainless steels with carbide, nitride or carbon-doped polymer coatings.

Normally, metal bipolar plates are manufactured by machining, but if low-cost mass production is desired, they must be manufactured by stamping.

2.3. Membrane Electrode Assembly (MEA).

It is made up of one electrode (the anode) that is fed with hydrogen and the other electrode (cathode), fed with oxygen, both being separated by the polymeric membrane that plays the role of the electrolyte.

Due to the need to use expensive catalysts such as platinum, the MEA is one of the most expensive parts of the fuel cell, but at the same time it has great potential for cost reduction. The lines of research that aim to reduce the costs of MEAs are focused on:

1. Use of alternative polymers to nafion.
2. Reduction in the amount of platinum used (increasing the operating temperature, for example).
3. Use of other less expensive catalysts.
4. Optimize catalyst dispersion.

The MEA has a cost reduction potential of 84%, and within the MEA, the parts with the greatest cost reduction potential are the electrodes (54%), because it is in them where the platinum is found, followed by the membrane.

There are two routes for preparing the MEA:

a. The preparation method of electrodes separately: The catalyst is deposited using appropriate techniques (painting, screen printing, airbrushing, etc.) on a conductive and porous carbon material (carbon paper), to which a Teflon solution is sometimes added, which, since it is hydrophobic, helps to expel the water that forms on the electrodes. Sometimes the gas diffusion layer is also added, although other times this layer is left as an independent sheet. Each electrode is finally assembled with the polymer membrane. The electrodes are assembled with the membrane by hot pressing at 140ºC.
b. Construction of the electrodes directly on the electrolyte: The carbon-supported platinum is deposited directly on the membrane. Therefore, the anode and cathode are manufactured directly on the electrolyte. As before, the gas diffusion layer can be added to the membrane - electrode assembly or can be retained as an independent layer. The construction of the electrodes directly on the electrolyte provides better adhesion properties, reduces the interfacial resistance between the different layers and improves the utilization of platinum, which translates into better battery performance.

2.4. Generator Set.

Various generating sets with various power sizes have been developed from fuel cells. In one of them we will connect. The Punta Salinas Maritime Rescue tugboat.

The 100 kW generator set is designed to operate efficiently (>52%) in the power generation range of 20 to 100 kW. Durability was predicted to be at least 5,000 hours with dynamic loading and start/stop profiles of equipment installed on board ground services.

The system will be able to operate in freezing conditions of up to -20 °C, because in some parts of the world we can encounter these situations. This will be achieved through a combination of shutdown and start-up procedures and some local electrical heating (mainly final cell heater, anode drain system heater). The system efficiency (from hydrogen input to DC output) will be greater than 50% at the start of life (BOL) as the cell voltage will be 0.72 V at full load operation and The compressor power will be less than 10 kW thanks to the use of the expander. The controller is a free programmable automotive ECU. A hardwired safety circuit will safely shut down the system in the event of a major controller malfunction.

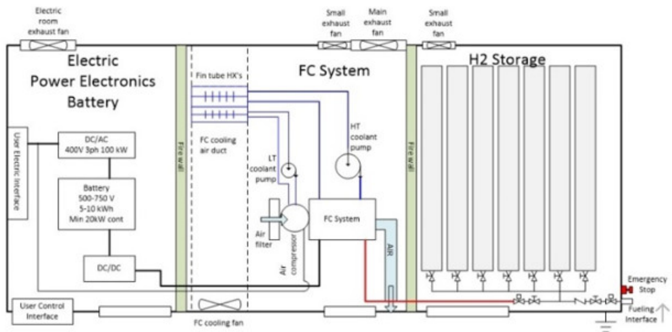
For a robust and easy-to-install solution, the fuel cell system and hydrogen storage will be installed in a single 20-foot (6.00×2.35×2.39 m) container. This will allow the system to be transported and installed while maintaining all electrical and gas connections already present.

3. Results.

3.1. Ground.

Once we have the generator set ready to connect from the ship, we proceed with the ground connection as follows:

Figure 3: Generator set.



Source: Authors.

<u>Personnel with PPE</u>

Before making the connection, the crew will be equipped with the necessary PPE (helmet, boots, gloves, etc.) required in all safety lists to comply with PRL 31/1995 regulations.

<u>Check connections and cables</u>.

Before proceeding with the connection, all connectors and cables will be checked, as well as their condition. If they are not in optimal condition, the department will be notified to study their repair or change.

Figure 4: Cable connector.

Source: Authors.

<u>Ground connection in the box</u>.

The crew will ensure that the ground connection is disconnected.

Figure 5: Ground Connection.

Source: Authors.

<u>Turn off equipment</u>.

It is necessary to turn off all equipment that is likely to be damaged by a possible plant fall.

<u>Minimum load</u>.

It is essential to leave the minimum load on the plant, when making the change, and when we are connected to ground, add load little by little.

<u>Connection</u>.

Once all the actions prior to connection have been carried out and checked, we proceed to connect to ground.

Figure 6: Ground Connection.

Source: Authors.

<u>Selector Position</u>.

Once plugged in, the selector is placed on the ground in the new box. The sequence of phases is checked; if it rotates in the opposite direction, it will be necessary to change two phases.

Figure 7: Selector.

Source: Authors.

<u>Disconnection of the main generator</u>.

At this moment, we proceed to lower the machete from the main on-board generator.

Figure 8: Panel.

Source: Authors.

Check consumption.

Once the entire connection process has been completed, it will be verified that the consumption and operation of all the equipment is correct. In addition, we can connect all the services required on board while we are docked, without exceeding 100 kW of power.

Hydrogen Supply.

For our battery, it is necessary to bring a supply of pressurized bottles between 200 and 300 kg/cm2 of liquid hydrogen by land transport and they are grouped in blocks of 15 bottles per group to carry out the supply.

The connections to the stack are 3 groups of bottles that are consumed in series. Depending on the electricity consumption, it will take more or less for the fuel to run out, but on average they have an autonomy of 7 hours. Once all the hydrogen is used up, they must replace the group of bottles so that the electricity supply does not cease.

Conclusions.

Grounding in the context of hydrogen fuel cells refers to the electrical grounding methods and practices used to ensure safety and reliability in hydrogen fuel cell systems. Here are some conclusions and considerations regarding grounding in hydrogen fuel cells:

1. **Safety and Explosion Prevention**: Hydrogen is highly flammable, and proper grounding is essential to prevent static electricity buildup, which could lead to sparks and potential explosions. Effective grounding reduces the risk of ignition in the presence of hydrogen.
2. **System Reliability**: Grounding helps ensure the reliability of the fuel cell system by providing a stable reference point for electrical components. This stability is critical for the accurate operation of sensors, controllers, and other electronic devices.
3. **Regulatory Compliance**: Adhering to grounding standards and guidelines is often mandated by regulatory agencies. Compliance with codes such as the National Electrical Code (NEC) in the U.S. or relevant international standards is necessary for the safe operation of hydrogen fuel cell systems.
4. **Equipment Protection**: Grounding protects equipment from electrical surges and faults. In the event of a short circuit or other electrical failure, a properly grounded system can help direct excess current away from sensitive components, minimizing damage.
5. **Design Considerations**: The design of grounding systems for hydrogen fuel cells must consider factors such as the location of the system, environmental conditions, and the specific configuration of the fuel cell and its components.
6. **Ongoing Monitoring**: Regular inspection and testing of grounding systems are essential to ensure ongoing effectiveness. Any degradation or failure in the grounding system can compromise safety and system performance.
7. **Training and Awareness**: Personnel involved in the operation and maintenance of hydrogen fuel cell systems should be trained in grounding principles and practices to promote a culture of safety.

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