



Introduction to Fuel Cells for Decarbonization

An Online Continuing Education Course for Engineers

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Introduction to Fuel Cells for Decarbonization

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A fuel cell is an electrochemical device that uses hydrogen or hydrogen-rich fuel and an oxidant to make energy. Fuel cells are increasingly seen as a reliable green energy alternative to polluting processes based on combustion from diesel and gasoline engines to coal-burning power plants. Rather than burning fuel to create electricity, fuel cells rely on an electrochemical reaction—which does not produce greenhouse gases. They offer significant energy efficiency and decarbonization benefits to a range of industries—including stationary power generation, automotive and heavy transport.

Fuel cells can run on a wide range of fuels, ranging from gaseous fuels such as hydrogen and natural gas to liquid fuels such as methanol and gasoline. If pure hydrogen is used as a fuel, fuel cells emit only heat and water as a byproduct.

Various types of fuel cells have been developed over the last few decades, such as Alkaline fuel cell (AFC), Direct Methanol fuel cell (DMFC), Phosphoric Acid fuel cell (PAFC), Molten Carbonate fuel cell (MCFC), Solid Oxide fuel cell (SOFC), and Proton Exchange Membrane (PEM) fuel cell.

This course introduces fuel cell technology and explores the merits and downsides of various fuel cell types, as well as their appropriateness for various applications. The course also aims to present the technical and economic challenges of introducing this technology.

Learning Objectives:

At the completion of this course, the readers will understand,

- Working fundamentals and performance of the fuel cell technology
- Advantages and disadvantages of fuel cells
- Applications of fuel cells in transportation and stationary power generation
- Operating principles and chemical reactions of different types of fuel cells
- Comparative advantages and disadvantages of different kinds of fuel cells
- Detailed construction of PEM fuel cells and fuel cell stacks
- Effect of various parameters on PEM fuel cell performance
- Cost economics of fuel cells

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1 Chapter - 1: Fuel Cells

1.1 Introduction

A fuel cell is an electrochemical device that generates electrical energy from fuel via an electrochemical reaction. The process is the reverse of water electrolysis, in which an electric current breaks down water into hydrogen and oxygen ions. In fuel cells, hydrogen (fuel) and oxidizer (oxygen or air) react chemically to generate electricity, heat, and water.

Fuel + oxidant → electricity + heat + water

In many ways, the fuel cell is analogous to a battery. The key difference between batteries and fuel cells is that while batteries store energy, fuel cells produce electricity continuously if fuels are supplied.

The first commercial usage of fuel cells was in the 1960s, when NASA utilized them to power satellites and space shuttles. Fuel cells have since been used in many applications ranging from portable gadgets, automobiles, and stationary power generation.

1.2 Components of a Fuel Cell

The working of fuel cells is simple. It contains three main components:

- a. Anode
- b. Cathode
- c. Electrolyte

1.2.1 Anode

The anode is the negative post of the fuel cell. It is the electrode where oxidation takes place. It conducts the electrons that are freed from the hydrogen molecules so that they can be used in an external circuit. It has channels attached to it that disperse the hydrogen equally over the surface of the catalyst.

1.2.2 Cathode

The cathode is the positive post of the fuel cell. It has channels etched into it that distribute the oxygen to the surface of the catalyst. It also conducts the electrons back from the external circuit to the catalyst, where they can recombine with the hydrogen ions and oxygen to form water.

Both anode and cathode are made from a thin carbon fiber paper which allows the active gases to pass through, and the electrode surfaces support platinum catalysts. Carbon fiber paper is commonly used because it is porous, hydrophobic, and non-corrosive. The most commonly used catalyst is platinum.

1.2.3 Catalyst

A catalyst is a material that speeds up a chemical reaction without being consumed. Platinum is a special material used as a catalyst in fuel cells. It is a precious metal that is so rare and expensive that it is often referred to as "white gold." Platinum is used in fuel cells because it is a very effective catalyst for the oxygen reduction reaction. The amount of platinum used in a fuel cell is a significant factor in the cost of the cell. Platinum is a heavy metal that is found in small amounts in the Earth's crust. It is a soft, malleable metal that is resistant to corrosion. It is used in a variety of applications, including jewelry, catalytic converters, and fuel cells.

1.2.4 Electrolyte

The electrolyte is the medium through which the ions flow. In a fuel cell, the electrolyte is typically a liquid or a solid. It is responsible for conducting the hydrogen ions from the anode to the cathode. The electrolyte must be able to conduct ions while preventing the gases from mixing. There are several types of electrolytes used in fuel cells, including alkaline, phosphoric acid, and proton exchange membrane (PEM).

1.3 World

Fuel cells were first developed in the 1960s for use in space exploration. They were used to power the Apollo space missions. Today, fuel cells are being used in a variety of applications, including power generation for homes, businesses, and transportation. Fuel cells are a clean, efficient, and quiet source of power. They are also being used in portable power applications, such as for military and emergency power. Fuel cells are a promising technology for decarbonization.

The schematic diagram of the fuel cell is provided below.