INVESTIGATING THE INFLUENCE OF OPERATING CONDIDTIONS FOR HYDROGEN FUEL CELL VEHICLE

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ABSTRACT

This study aims to show the influence of driving cycles in the performance, efficiency, and emissions of hydrogen fuel vehicles. Hydrogen Fuel Cell Vehicles (HFCV) represent the most promising solution for reducing the greenhouse gas emissions and dependence of fossil fuels in the transportation field. However, the performance of HFCV may vary based on different driving conditions and environmental factors. To explore the performance of various driving cycles which represent the real-world scenarios are analyzed including highway, urban and mixed driving conditions. Through comprehensive analysis this study investigates how different driving cycles affect the operational characteristics of hydrogen fuel vehicles. The simulation was conducted based on the MATLAB/Simulink software to show overall performance of HFCV.

KEY WORDS

Hydrogen Fuel Cell Vehicle (HFCV), Driving Cycle, Efficiency, 1-D simulation

1. INTRODUCTION

Hydrogen fuel cell vehicles (HFCVs) are a highly promising option for sustainable transportation, offering zero emissions and high efficiency. These vehicles generate electricity by combining hydrogen gas with oxygen in a chemical reaction, with water vapor as the only byproduct, making them an environmentally friendly alternative.[1]

The core component of HFCVs is the proton-exchange membrane fuel cell (PEMFC), which operates through an electrochemical reaction between hydrogen and oxygen. The reactions at the anode and cathode proceed as follows:[2]

$$H_2 \rightarrow 2H^+ + 2e^- \quad (1)$$

and

$$1/2O_2 + 2H^+ + 2e^- \rightarrow H_2O \quad (2)$$

At the anode, hydrogen molecules are separated into protons and electrons. The protons pass through the Proton Exchange Membrane (PEM) to reach the cathode, where excess water is released. Meanwhile, the electrons travel through an external circuit, generating an electric current that powers the vehicle's motor.[5] Utilizing PEMFC technology in vehicles not only produces no harmful emissions, but also substantially reduces greenhouse gas emissions.

However, relying solely on the proton-exchange membrane fuel cell in vehicles can lead to performance degradation and damage to the PEM, reducing the vehicle's overall durability.[3] This is why integrating a battery into hydrogen fuel cell vehicles is essential. Due to hydrogen's relatively recent application in transportation, scientific research in this area remains limited.[4]

My research addresses these gaps by studying the integration of batteries with PEMFCs in heavy-duty hydrogen fuel cell buses. Through simulation of various scenarios—including different driving conditions, thermal control, and management strategies—my work seeks to determine which operating modes can extend the fuel cell's lifespan while enhancing overall vehicle durability and efficiency. Additionally, I will examine how the HVAC system impacts overall vehicle performance.

2. METHODOLOGY

2.1 Research Design

The research utilized MATLAB/Simulink software to model, simulate, and analyze the performance of the fuel cell and battery systems in hydrogen fuel cell vehicles (HFCVs).

2.2 Simulation Condition

Table 1, 2 shows the parameters that are used in simulation. The parameters are shown for heavy bus vehicles.

Table 1: Battery Parameters.

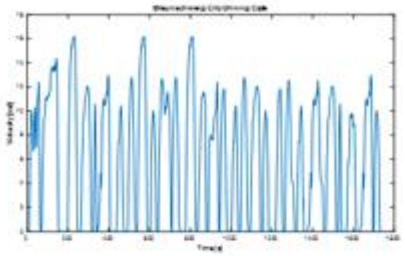
Battery Parameter	
Voltage	642 V
Capacity	72 Ah
Initial SOC	60%

Table 2: Fuel Cell Parameters.

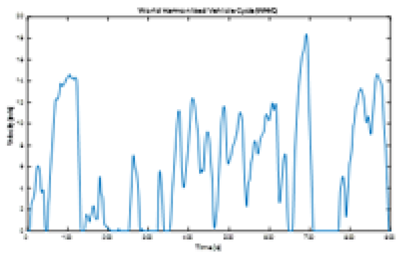
Fuel Cell Parameter	
Cross-section area	4500 cm^2
Number of Cells	200-500
Capacity	Max. 180 kWh

In the simulation, the bus weight is set at 11 tons, which includes the chassis, engine, and a standard passenger load. This weight was selected to reflect the average weight of standard city buses. For the battery, parameters such as voltage and capacity, shown in Table 1, were considered alongside the fuel cell's capacity and the number of cells per stack. This research focuses on optimizing fuel cell performance and fuel consumption, so the fuel cell stack capacity is set to its maximum value rather than being fixed. By adjusting the capacity of the fuel cell stack, the study aims to identify the optimal operating mode for the HFCV.

2.3 Driving Conditions



(a)



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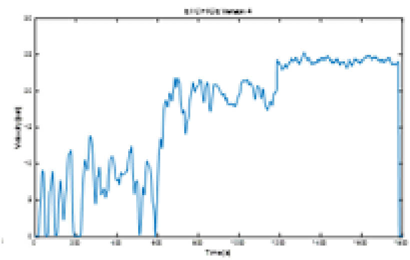

(c)

Fig: 1 (a) The Braunsehweig Cycle, (b) The World Harmonized Vehicle Cycle (WHVC), (c) European Transient Cycle (ETC) driving conditions [6]

Figure 1 shows the evaluation of three driving conditions to identify the most effective driving mode for increasing efficiency in the simulation. The Braunschweig Cycle was tested as it best represents urban environments with frequent stop-and-go traffic. The World Harmonized Vehicle Cycle (WHVC) was used for highway scenarios, and the European Transient Cycle (ETC) represented mixed segments, including urban, rural, and highway conditions. These driving conditions provide realistic scenarios for bus operation, reflecting the diverse and challenging environments that buses encounter. Each setting was used to analyze fuel cell consumption efficiency and the overall reliability of the vehicle.

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