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Fuel cells for airborne usage: Energy storage comparison

F. Ustolin*, R. Taccani

Università degli studi di Trieste, Dipartimento di Ingegneria e Architettura, Trieste, Italy

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ABSTRACT

The global drone market is growing every year. The number of applications is increasing: from search and rescue, security, surveillance to science and research and unmanned cargo systems.

A limiting factor for drone exploitation is that for the energy storage, normally, a battery is used and this solution affects flight time. A possible solution could be the utilization of fuel cells. This paper focuses on the utilization of fuel cells power as an alternative solution for drone propulsion.

The aim of the study is to determine when it is more appropriate, in terms of mass, to use a battery or a hybrid (fuel cell + battery) system to power drones. To compare the different systems, a numerical simulation model has been developed in order to choose the best power system once the drone operation profile has been defined.

The model allows comparing different type of fuels and battery systems. The data to tune the model have been taken from commercial products, today already available. The simulation model considers a light-weight open-air cathode PEM (Polymer Exchange Membrane) fuel cell. The stack power output is chosen according to the mission profile and rages from 200 W to 1000 W.

The presented results show that, for the considered drone segment, multirotor drones with weight of 7 kg at take-off, lithium batteries are still the best choice for time flight shorter than about 1 h. A hybrid system, appears to be interesting for longer flights. For example, it has been calculated that a hybrid quadcopter drone with a mass of 7 kg, considering a flight profile that requires 1089 Wh can be powered with a 4.4 kg hybrid system composed by a 500 W and 1.4 kg PEM fuel cell system, 1.9 kg hydrogen composite pressure vessel and a 0.8 kg lithium battery. The same amount of energy can be stored in a lithium battery with a weight of about 6.6 kg. These means a weight saving of more than 30%. The hybrid system, in term of weight, is even more convenient for flight profiles that require more energy.

Introduction

The global drone market is growing every year. The number of applications is increasing: from search and rescue, security, surveillance to science and research and unmanned cargo systems. Several market forecast agency show very promising figures for the drone market, as shown in Table 1.

* Corresponding author. Università degli studi di Trieste, Dipartimento di Ingegneria e Architettura, Via Valerio, 10, 34127, Trieste, Italy.
E-mail address: fustolin@units.it (F. Ustolin).

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Acronyms

AUVSI	Association for Unmanned Vehicle Systems International
BMS	Battery Management System
BoP	Balance of Plant
CNG	Compressed Natural Gas
ENAC	Ente Nazionale Aviazione per l'Aviazione Civile
FC	Fuel Cells
HES	Horizon Energy System
LHV	Low Heating Value
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MTOW	Maximum Take-Off Weight
MUAV	Multirotor Unmanned Aerial Vehicle
PEM	Polymer Electrolyte Membrane
SOC	State Of Charge
TMS	Thermal Management System
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle

Today, most of the commercial drones are electric and they are powered by batteries. Batteries have many drawbacks when professional users want to employ the drones in some specific applications. Firstly, the main problem is the endurance of the batteries. Nowadays, for the professional drones, the flight time is, normally, limited to 40 min [1].

Secondly, the batteries charging time is still very long in comparison with the refilling time of fuels for devices such as internal combustion engines or fuel cells. One possible solution to expand the use of the drones to more applications could be the development of a hybrid power supply system composed of fuel cells and battery. Fuel cells are generator fuelled by hydrogen. Hydrogen is the lightest element in nature and it has a high LHV that is almost 120 MJ/kg, three times higher than gasoline [2]. This is why fuel cells, potentially, could have a high specific energy. Professional drones have discontinuous operating conditions and they do not work all the flight time at the maximum power. Therefore, fuel cells could work at a constant power while battery overcomes the power peaks during the flight. This is why a hybrid system could be interesting.

Another benefit of using fuel cells is that they need just few minutes to refill the tank if pressurized hydrogen is used. Furthermore, at the end of the operating life, most of the fuel cells components can be recycled or reused. One of the biggest fuel cell drawback is the high cost [3].

The aim of this study is to determine when it is more appropriate, in terms of mass, to use a battery or a hybrid (fuel cell + battery) system to power multirotor drones.

A drone market analysis and a literature review about drone powered by fuel cells have been carried out including an energy storage comparison for different type of batteries and fuels. In most cases, the literature regards only fixed wing drones, while this research focuses on multirotor drones. To compare the different power systems, a numerical simulation model has been developed in order to choose the best configuration once the drone mission profile has been defined. The model allows comparing different configurations of fuel cells and battery systems.

Drone classification

Professional drones vary significantly in look, specification, and price. The Italian ENAC regulations (Ente Nazionale per l'Aviazione Civile) [12], that follows the European EASA regulations, divides the professional drones in two large categories:

1. aircraft with operating mass at the take-off lower than 25 kg;
2. aircraft with operating mass at the take-off equal or higher than 25 kg and not greater than 150 kg.

The costs and regulatory restrictions of the first category are minor than the second, the majority of the professional drones do not have an operating mass at the take-off higher than 25 kg. The ENAC regulation subdivides this category in 3 additional classes:

1. drones with operating mass lower than 0.3 kg;
2. drones with operating mass between 0.3 and 2 kg;
3. drones with operating mass between 2 and 25 kg.

Professional drones used in most applications weigh more than 2 kg because they withstand better the different weather conditions and they can carry heavier equipment. Usually, professional drones weigh between 5 and 10 kg, but, for some applications, such as agriculture, they can weigh even more

Table 1 – Drone market forecast: analysis of different market research firms.

Market research firm	Year	Aerial drone market	Market size ($ Billion)	Until (Year)
Tractica [4]	2015	Commercial	12.7	2025
Teal Group Corporation [5]	2016	Total	11.5	2025
AUVSI [6]	2015	Total	10.1	2025
Lux Research [7]	2014	Commercial	1.7	2025
BI Intelligence [8]	2015	Total	12.6	2024
Markets and Markets [9]	2014	Small	1.9	2020
ABI Research [10]	2014	Small	8.4	2018
U.S. Consumer Electronic Association [11]	2014	Consumer	0.3	2018

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