Hydrogen-powered ultralight training aircraft – a systems engineering approach

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Aviation as a sector is responsible for ever increasing amount of harmful to environment emissions, including greenhouse gases of various kind, as well as oxides and dioxides of carbon, nitrogen and sulphur. With current industry approach of slow creep into slightly higher inter-turbine temperatures and bypass ratios, turbine engines specific fuel consumption improvements are stagnating with every new generation. To decisively close the pollution gap between reality and sustainability aviation industry must shift to where automotive giants went decades ago – electric propulsion, and in particular, hydrogen flight.

Application of hydrogen in aviation is nothing new – as far as 1970s serious resources have been put to use[1] into determining viability of using hydrogen as primary fuel for passenger airplane. This idea seems to be circulating aviation experts minds like an unfortunate comet, with new wave of papers and research emerging every few decades[2], but no commercial projects introduced up to date. This is surprising considering wide use of hydrogen in electric cars and forklifts, and begs the question – why?

There are multiple answers to this question, but one seems to be dominating the others – hydrogen in aviation has been always seen as a research project, and never as viable product. Technical barriers are both well-known and well researched - hydrogen storage is problematic both as a gas[3] and liquid[4] and magnitude of infrastructure investment needed scares any serious trials of commercialization. With lack of regulation for aircrafts and airports[5] (even specially developed ISO regulation 15594 was withdrawn in 2004) most hydrogen-related projects were planned as research-only.

As serious as aforementioned barriers are, a systems engineering approach[6] is applied to break them and develop minimum-viable product for hydrogen airplane.

Firstly, most important obstacles to commercialization are laid down, and abatements for all are proposed. The most viable abatement is determined to be a training airplane, developed in ultralight category, propelled with electric motor, powered by PEM fuel-cell stack, with hydrogen stored as high-pressure gas in composite tank onboard. This architecture posed challenges in the past, ever for the most successful hydrogen light projects (good examples of both UAVs[7][8], moto-gliders[9] and airplanes[10][11]) because of high complexity of propulsion system, different environmental requirements for each element and challenging integration.

As a next logical step, a series of different airplane configurations is proposed, with a goal of optimizing for hydrogen propulsion system integration. In fact majority of past projects challenges emerged from the fact they were converting already existing constructions into hydrogen airplanes. With architecture developed from ground-up with hydrogen propulsion in mind, final configuration is chosen and analysed. Airplane performance, as well as stability and controllability characteristics are presented and compared to competitive solutions, already available on the market.

In conclusion, a conceptual framework is laid down and proven, in which with already existing technology hydrogen airplane can be viable product, with characteristics and advantages comparative to already existing solutions.

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