FAKULTÄT TECHNIK UND INFORMATIK
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Passenger Aircraft towards Zero Emission with Hydrogen and Fuel Cells

Aircraft burning hydrogen in turbofan engines are not "zero emission". So, what is required?

According to the EU's "Green Deal", no more net greenhouse gas emissions should be released in 2050. All modes of transportation will have to contribute to this reduction. This includes also aviation. To keep things relatively simple here, the aircraft is considered the system boundary. This is called "tank-to-wake". The options to achieve "zero emission" flight (in these boundaries) are limited. Electric flight with batteries will be limited to short range for years to come. Burning hydrogen in jet engines would be a major step forward, but is clearly no solution to achieve "zero emissions", it emits NOx and produces potentially warming contrails. Electric flight with hydrogen and fuel cells could be an option. It has neither CO2 nor NOx emissions. It releases water in liquid form, but this seems not to be critical.

PURPOSE

This project evaluates the feasibility of passenger aircraft designed for Top Level Aircraft Requirements (TLAR) of the Airbus A320 using liquid hydrogen (LH2) and fuel cells to achieve "zero emissions".

METHODOLOGY

An existing preliminary sizing tool for jet and propeller passenger aircraft (CS-25) is modified to include all elements for LH2 storage and fuel cell integration including electric motors and heat exchangers. Current and possible future technology parameters are determined from a literature review.

FINDINGS

The first reference aircraft is the redesign of the A320. The second reference aircraft is a possible turboprop version of the A320 with a cruise Mach number of only 0.65. The turboprop version shows a fuel mass and Direct Operating Costs (DOC) of only 66.1% and 86.5% respectively. Related to the A320 redesign, the fuel cell aircraft has fuel energy and DOC higher by 140% and 221% based on current technology parameters. If plausible future technology parameters are considered, the same values are 74% and 146%. These results show that a fuel cell passenger aircraft is unfeasible with current technology and remains unlikely with future technology. Water emissions can neither be avoided by water storage in flight nor by discarding the water in flight in form of ice cubes.

RESEARCH LIMITATIONS

The impact of liquid water emissions during flight into the atmosphere needs to be investigated further, but seems not to be of major impact according to a recent publication.

PRACTICAL IMPLICATIONS

The new preliminary sizing tool for fuel cell passenger aircraft is made available and can be used for further studies.

SOCIAL IMPLICATIONS

So far large fuel cell passenger aircraft were seen as a possible solution to aviation's environmental problems. The general feasibility, energy requirements, environmental and economic impact of hydrogen-electric aircraft can now be discussed by the public

ORIGINALITY

It seems, there is so far no preliminary aircraft sizing tool for hydrogen-electric aircraft publicly available.

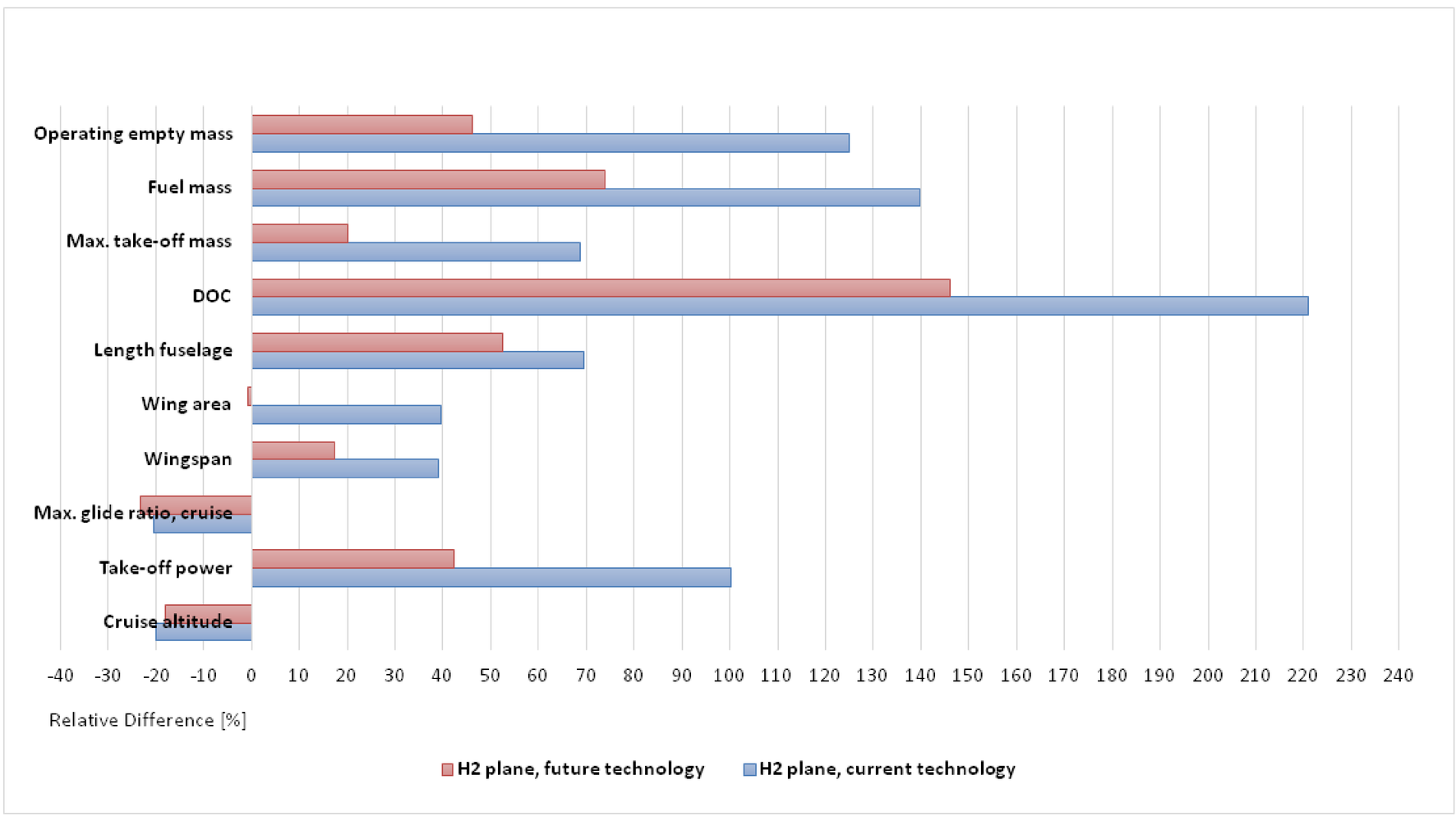

Figure 1: **Comparison of the A320 with a new A320 powered with liquid hydrogen (LH2), fuel cells, and electric motors. Results from preliminary sizing for two technology scenarios (current and future).**

All details in the Bachelor Project of Gollnow (2022):
https://nbn-resolving.org/urn:nbn:de:gbv:18302-aero2022-11-16.010

Associated research data (Harvard Dataverse):
https://doi.org/10.7910/DVN/CURS1U

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