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2.1: Evolving aircraft technologies contributing to LTAG

THE ROLE OF HYDROGEN IN AVIATION

(Presented by the International Coordinating Council of Aerospace Industries Associations (ICCAIA))

EXECUTIVE SUMMARY

ICAO has adopted a Long-term Aspirational Goal (LTAG) to reduce CO2 emissions from international civil aviation and has explored the potential of the mitigation options in the "basket of measures". Industry is pressing ahead to contribute to the achievement of this goal by developing technologies and concepts that contribute to CO2 emissions mitigation through the continued improvement of aeroplane and engine energy efficiency and through the use of cleaner aviation fuels and alternative energies.

Hydrogen propulsion for civil aeroplanes has the potential to significantly reduce an aeroplane's direct CO2 and non-CO2 emissions. Depending on the source of energy used to produce the hydrogen, overall systemic emissions could also be significantly reduced. This paper explores the various concepts that are under study, describes some key considerations when comparing hydrogen aeroplanes with conventionally-powered aeroplanes, highlights some of the ongoing challenges to bring hydrogen-power to the market and encourages co-operation between ICAO and the industry to facilitate the safe and seamless introduction of hydrogen aeroplanes into the international air transport system.

1. INTRODUCTION

1.1 The ICAO Long-term Aspirational Goal (LTAG) has determined a goal of Net Zero carbon emissions from international civil aviation by 2050. The decarbonization of aviation is already underway, with industry having commenced work on parallel pathways, including the use of Sustainable Aviation Fuels (SAF) and exploration of the use of alternative energy sources. Efforts will continue to be based on a range of mitigation measures, each with their own role to play and each with their own challenges. A large part of carbon emissions can be avoided by using these cleaner fuels and alternative energies, with hydrogen being one such solution. It poses major challenges and also constitutes an opportunity for the sustainable development of the aviation sector.

1.2 Currently over 99 per cent of the hydrogen consumed by the transportation sector originates from fossil sources[1]. In order to be an effective contributor to aviation's Net Zero target, it is essential that

[1] IEA (2023), "World Energy Outlook 2023"

renewable and low-carbon hydrogen be used to power aeroplanes. The advantages and challenges are discussed below.

2. DISCUSSION

2.1 Cleaner and alternative energies with lower lifecycle impact have been assessed as critical to the decarbonisation of the air transport sector by ICAO (ICAO LTAG report[2]). Hydrogen is seen as one promising vector in the basket of measures identified in the report and will require significant support of all aviation stakeholders in the ecosystem to make use of hydrogen a reality in the coming decades.

2.2 Today's Hydrogen economy consists of around 100 Mt being consumed annually, but with over 99 per cent originating from fossil sources[3]. Existing players, along with new potential consumers, are looking to pivot the sector towards full low-carbon hydrogen production. It will be essential, as with all energy types, to include the full lifecycle of emissions from hydrogen production and use in assessment of sustainability impact.

2.3 With respect to aviation, hydrogen has two potential uses:

a) as a feedstock input to produce Sustainable Aviation Fuels (SAF), or;

b) as a direct fuel, in either gaseous or liquid form, to either be reacted in fuel cells or combusted in hydrogen engines.

2.4 Regarding 2.3 a), SAF has already been identified as a very significant contributor to aviation's Net Zero target, and many stakeholders are fully engaged in enabling widespread use of SAF alongside ICAO. The main advantages, identified separately in AN-Conf/14-WP/25, relate to the fact that the changes required to the air transport system are low compared to those for other energies. Power to Liquid (PtL), which is based on the synthesis of CO2 and green hydrogen from renewable sources, has the potential to deliver significant quantities of SAF in the future. However, significant investment in energy infrastructure will be required.

2.5 Regarding 2.3 b), given the need to look at multiple solutions to meet emissions goals for the longer term projected growth, manufacturers are working on disruptive-technology hydrogen propulsion systems, whether they be designed purely for the use of hydrogen or be designed for "dual fuel" SAF and hydrogen use.

2.6 As with other alternative energy propulsion systems, it is likely that hydrogen powered aeroplanes will be introduced in the regional sector first, after which increasingly larger and longer-range products could enter the market place (single aisle/narrowbody and later long range/widebody aeroplanes).

2.7 It is very likely that new policies, recommended practices, regulation and, potentially, incentives, would be needed.

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[2]ICAO Report on the feasibility of a long-term aspirational goal (LTAG) for international civil aviation CO2 emission reductions: https://www.icao.int/environmental-protection/LTAG/Documents/REPORT%20ON%20THE%20FEASIBILITY%20OF%20A%20LONG-TERM%20ASPIRATIONAL%20GOAL_en.pdf

[3] IEA (2023), "World Energy Outlook 2023"

2.8 The use of liquid and gaseous hydrogen in aviation introduces needs, challenges, risks and opportunities that are new to the field. Because of this, existing regulations and standards may not be applicable. As the aviation industry strives to overcome the technical challenges of hydrogen propulsion for aviation, a variety of technologies, systems and aeroplane architectures are being explored, with new projects emerging on a regular basis.

2.9 Regulatory frameworks will need to provide flexibility as technology evolves, while focusing on high level safety objectives. This is best achieved through the development and introduction of performance-based and technology-agnostic Standards and Recommended Practices (SARPs).

2.10 The industry is already developing recommended practices specific to hydrogen aeroplanes through the development of industry consensus standards undertaken within the framework of Standards Development Organizations (SDOs) such as SAE, European Organisation for Civil Aviation Equipment (EUROCAE), ASTM and International Organisation for Standardisation (ISO). To achieve this, the aviation industry is relying on a body of reference standards produced by other industries, some of which have been using hydrogen and hydrogen technologies for decades. This work may assist ICAO in its own standards making activities.

2.11 Additionally, some work is already being undertaken in ICAO. Notably a Job Card tasking the Aerodrome Operations Working Group with leading all activities required to support the introduction of aircraft powered by “alternative energies” such as hydrogen at Aerodromes has been launched. Areas of particular attention will be rescue and fire fighting (RFF) at aerodromes, and aeroplane handling procedures for “alternative energies” as these may differ from those of currently existing fuel types.

2.12 As with most disruptive technologies, hydrogen will require significant investment in infrastructure and an entire ecosystem will need to be developed for the production and supply. Airport adaptation to accommodate hydrogen power is likely to be significant, with the need to either produce hydrogen locally, which itself requires a significant consumption of electricity; or alternatively to transport hydrogen. Storage facilities for hydrogen fuels will be needed. All of this hydrogen specific infrastructure will necessarily be in parallel to the existing infrastructure required for the storage and supply of kerosene/SAF.

2.13 Adjustments will also have to be made in the interface between airport infrastructure and the aircraft, with one main point of attention being during refuelling, maintenance or defueling as hydrogen’s flammable nature will require special handling procedures. Considerations related to leak detection and monitoring, fire suppression systems suitable for hydrogen, safety training for personnel involved in handling and managing the hydrogen, personnel protective equipment or regulatory compliance will be needed.

2.14 The challenge in constructing and operating hydrogen infrastructure at airports will be significant, with the earliest hydrogen-powered (whether pure hydrogen or dual-fuel) aeroplanes likely to come to market in the next decade. Beyond this, it is anticipated that more aircraft powered by alternative energies will likely be introduced, starting around 2035. It will be important to converge on technical and regulatory aspects in a timely way to facilitate their introduction, which means a SARPs development between 2030 and 2035.

2.15 Some early synergies might be possible, however, as hydrogen fuel can also be used for powering ground equipment. Such a concept would lead to the airports becoming a “hydrogen hub” and is one of the key founding blocks of the route to hydrogen deployment (both gaseous and liquid) for aviation decarbonisation. A stepped approach can be explored, first transitioning ground equipment and progressively introducing infrastructure until it is ready for the supply to aeroplanes. The Appendix to this paper describes some key elements and considerations for airports.

3. CONCLUSION

3.1 The decarbonization of air transport is underway in line with the Long-term Aspirational Goal of Net Zero carbon emissions from international aviation by 2050. It will involve the emergence and rise of cleaner, renewable, parallel and complementary energies such as SAF and hydrogen.

3.2 Industry is currently focused on developing technical solutions relevant to the design and operation of hydrogen aircraft, acknowledging that there are many challenges to be addressed along the way. Hydrogen will have a role to play in the decarbonisation journey going forward – either as a feedstock for PtL SAFs or used directly as a fuel - and it is important that all stakeholders begin to lay the groundwork to allow this disruptive technology to enter the fleet in a timely way. Initial work on SARPs has begun in some areas, and an increasingly holistic approach across all Annexes will be required for all alternative energies, including hydrogen.

3.3 As mentioned in 2.14 above, to facilitate the introduction of hydrogen aircraft from approximately 2035 as defined in the LTAG Report's technology roadmap, work to bring together the technical and regulatory aspects will be needed between 2030-2035.

3.4 The industry appreciates the essential role that ICAO plays in spearheading the development of a globally harmonised regulatory framework for hydrogen in aviation and is fully committed to supporting ICAO and its panels to achieve this goal.

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APPENDIX

ELEMENTS OF THE HYDROGEN END-TO-END SUPPLY CHAIN:

The general characteristics of the elements that will constitute the end-to-end low carbon hydrogen supply chain up to the airport are summarised below, from production to airport storage to refuelling.

- HYDROGEN PRODUCTION

  Hydrogen production plant:
  Hydrogen is first produced in gaseous form, and then liquefied as needed. Both operations may take place at the same location or may be distant.

  There are many different ways to produce gaseous hydrogen: Steam-methane reforming (with or without CO2 capture), auto-thermal reforming, water electrolysis, coal gasification, methane cracking, etc. Water electrolysis, using renewable or low-carbon electricity, is the production method that has one of the lowest carbon footprint.

  Hydrogen liquefaction plant:
  Liquefaction plants mainly consist of several cycles of gaseous hydrogen compression/decompression and cooling down. They require much less electrical power than an electrolysis plant so will not necessitate high-voltage power lines.

- LIQUID HYDROGEN (LH2) TRANSPORTATION

  LH2 tanker truck:
  Liquid hydrogen has been transported in road trailers for decades. They include a highly insulated tank that is able to keep boil-off levels to a minimum for several days. LH2 tanker trucks circulating in Europe have a maximum capacity of 3,5 tons, while tanker trucks circulating in North America can carry up to 4 tons.

  LH2 tanker ships
  Airports that have immediate access to a river or a sea coastline may also be supplied by LH2 tanker ships. Such ships do not exist yet except for a prototype developed by KHI in Japan, but several are under development with various capacities.

  Gaseous hydrogen pipeline:
  Pipelines can efficiently carry large amounts of gaseous hydrogen over long distances. In many cases it should be possible to convert existing natural gas pipelines to transport hydrogen without having to make major modifications. There are ambitious plans to build-up hydrogen pipelines networks in Europe (European gas backbone) and in North America, so this mode of transport could become common in the mid-term future.

- LIQUID HYDROGEN STORAGE

  LH2 is usually stored in highly insulated cylindrical tanks (“bullet” tanks), which may be installed in a horizontal or in a vertical position. For very large capacities spherical tanks may also be built, as a spherical shape reduces heat exchanges with ambient air to a minimum.

LH2 storage sites usually feature loading bays for trucks to refill the tanks, unloading bays to transfer LH2 to tanker trucks, and vent masts to evacuate excess boil-off.

AIRPORT HYDROGEN INFRASTRUCTURE TYPOLOGY AND SIZING:

The pattern used to supply an airport with hydrogen will depend on many factors: quantities needed, size and location of the airport, local hydrogen ecosystem, etc. 3 main supply patterns will be considered: Remote, On-site, and Mixed. In the specific case of coastal airports, a ship-based supply scenario can also be considered.

- REMOTE SCENARIO

  In this scenario, hydrogen is produced and liquefied at a production plant away from the airport. It is transported to the airport by LH2 tanker trucks. When arriving at the airport several options can be considered. This pattern is therefore suitable for daily LH2 consumption of up to 30 to 50 tons.

- ON-SITE SCENARIO

  In this scenario hydrogen is produced, liquefied and stored at the airport. A fleet of captive refuelling trucks is loaded at the storage site. Hydrogen liquefaction plants start to be economically viable when they reach high production capacities. This pattern will therefore not be suitable for airports with low levels of traffic. Considering the necessary investment, it will only be deployed for daily LH2 consumption of at least 30 tons. This could be a highly energy intensive process that may be challenging to implement at airports when compared to a mixed scenario.

- MIXED SCENARIO

  In this scenario hydrogen is produced away from the airport. It is transported to the airport in gaseous form, using pipelines, and is thereafter liquefied and stored at the airport. A fleet of captive refuelling trucks is loaded at the storage site. This pattern is similar to the full "on-site" pattern, so it will also be deployed for daily LH2 consumption of at least 30 tons.

- SHIP SUPPLY PATTERN

  This scenario is only applicable to airports that have direct access to the sea or to appropriate waterways. In this case liquid hydrogen is produced away from the airport and transported by specialized ships or barges. In theory, this supply scenario could be applicable to a wide range of traffic levels, thanks to the scalability of the ship supply, of the associated storage and fleet of captive refuelling trucks. However the investment required for the ship terminal is high and will not be justified for small airports

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