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2.1: Evolving aircraft technologies contributing to LTAG

THE STATE OF THE ART OF ELECTRIC PROPULSION SYSTEMS

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

EXECUTIVE SUMMARY

All-electric propulsion systems for civil aeroplanes can potentially significantly reduce CO2 and other emissions at the vehicle level, and overall depending on the source of the electricity used to charge battery systems. This paper explores the various concepts that are under study and/or test, describes some key considerations when compared to conventionally-powered aeroplanes and encourages the continuation of a close relationship between ICAO and the industry to facilitate the safe, seamless introduction of such concepts into the fleet.

1. INTRODUCTION

1.1 In its contribution to the work of the Long-term Aspirational Goal (LTAG) for carbon reduction technologies, the International Coordinating Council of Aerospace Industries Associations (ICCAIA) provided information regarding several novel technologies that are envisaged to have a role in reducing the CO2 emissions for international aviation. One such technology is ‘Electric’ or ‘All-Electric Propulsion’.

1.2 A number of aircraft programs over the last two decades have made use of electric propulsion systems on an experimental basis. Almost all of those aircraft would be classified as “General Aviation” aeroplanes, being single engine, small aircraft with a limited range. Some have been simply test vehicles or technology demonstrators while others have made it to limited production. However, the advent of Advanced Air Mobility (AAM) vehicles and projects for small commuter type aircraft between 6 and 19 seats have made consideration for operation under international Standards increasingly relevant.

1.3 Some of the project aeroplanes could be offered with either all-electric or hybrid-propulsion systems, depending on customer need. However, this paper will only consider all-electric configurations as AN-Conf/14-WP/23, “*The State of the Art of Hybrid Propulsion Systems*” considers hybrid-propulsion variants separately.

1.4 For the purposes of this paper, electric aircraft are defined as those using batteries for energy storage and supply, driving electric motors.

2. DISCUSSION

2.1 As mentioned above, a number of “General Aviation” technology demonstrator all-electric aeroplanes have been developed over the last two decades, including the Taurus Electro, the Airbus eFan and the Rolls-Royce ACCEL. Other companies have gone on to announce, or produce, serial production of all-electric aircraft, including Pipistrel and Diamond aircraft.

2.2 In general, these manufacturers have elected to use lithium ion batteries for energy storage. These aircraft have demonstrated that, while all-electric flight is feasible, the applications up to now have been quite limited due to the difference in energy density (i.e. power developed per unit of weight) of batteries versus conventional fuel. Conventional Jet A1 fuel has an energy density of, typically, 12,000 watt hours per kilogram (wh/kg). By contrast, a typical lithium ion battery has an energy density of around 250 wh/kg. Even with some battery manufacturers claiming that they can reach 450 wh/kg, the contrast is stark.

2.3 For civil aviation, the consequence of having such a high weight for the amount of energy stored is a severe restriction on the payload, the range or both. Consequently, the passenger-carrying, transport-category aeroplanes that are currently envisaged to utilise batteries for all-electric flight are small – between 6 and 19 passengers – and have a limited range, below 300 nautical miles.

2.4 Currently two transport-category all-electric aeroplanes are at various stages of operation and testing, with a 6-passenger, electrically powered DeHavilland Beaver conversion undergoing testing using an 850 shaft horsepower (SHP) electric motor weighing 135 kg; and the twin-engine, 9 passenger (+ 2 crew) Eviation Alice also undergoing testing. A cargo version of the Alice for use as an express parcels aircraft is also envisaged.

2.5 A third aeroplane, the 19-seat Heart Aerospace ES-19 has recently been cancelled in favour of a hybrid-electric 30-seater. This switch to hybrid power emphasises the current difficulties associated to all-electric flight. As a consequence of the power-density and consequent payload-range limitations offered by current and foreseeable battery technology, the use of pure electricity for passenger category aeroplanes is limited. Although it is likely that some commuter type aircraft will come to the market over the next decade, it is unlikely that all-electric aircraft of the size and range capability of today’s turboprop and regional jet airliners will appear for quite some time.

2.6 That said, the advent of Advanced Air Mobility (AAM) vehicles has caused a re-examination of the development of electric flight. All of the currently-flying AAM projects make use of battery-electric technology, though the mission profile of an AAM aircraft and a commuter aeroplane are significantly different. However, with multiple AAM projects underway, research into better and more efficient battery technology and even lighter motors has been renewed.

2.7 The reduction in CO2 (and other emissions) by electric aircraft is highly dependent on the source of the electricity used to charge the batteries of the aircraft. While there are no gaseous emissions at source, and relatively low noise, the risk is that the emissions are simply displaced to the point of energy generation. It is therefore important that airports either have access to, or generate their own, clean energy. Since many ground vehicles at airports are becoming electrically powered, and since hybrid aircraft are also likely to need a charging network, there are significant synergies to be made. Disposable and end-of-life environmental impacts of these batteries will also need to be considered.

2.8 Airports will also need to take account of the infrastructure needed to support these aeroplanes and their technologies. They will need to charge the batteries while the aircraft is at the gate, or change battery packs on the ramp, depending on the design. Power generation and distribution sufficient to recharge the batteries, either at the gate or at a remote location will be needed. A common standard for the connectors between the aircraft and the ground infrastructure is also needed to facilitate the transfer of aeroplanes between airports and regions. Ramp space to accommodate the additional battery servicing vehicles, including any increased safety distances, will also be required.

2.9 In case of an accident, emergency personnel will need to be equipped and trained to be aware of potential battery-fires and other battery-related emergencies (e.g. leakage in case of aircraft damage).

2.10 Engine start up and shutdown procedures also have the potential to be different, and an engine run-up area for aircraft that have taxied using electrical power driving the wheels may be required, as may be a dedicated area for engine cool down at the end of flight.

2.11 Regarding certification and airworthiness, electric aircraft are also likely to have some different needs and requirements. For example, as energy is used, the aeroplane's mass remains constant, unlike a conventionally powered aircraft that burns fuel and becomes lighter during the mission. This leads to two critical differences compared to a conventional aeroplane. Firstly, the landing weight of the aeroplane is the same as the take-off weight as fuel is not consumed during the flight, leading to the landing gear and airframe structure being sized accordingly. Secondly, conventional liquid-fuelled aeroplanes climb to higher cruise altitudes with less dense air during the flight as they burn off fuel. This will not be the case for an electric aircraft, whose ceiling will not vary with distance as the weight of the vehicle remains constant throughout the mission. Consideration will also have to be given to the management of batteries whose energy storage capability may diminish with time.

2.12 Additionally, the reserves policy will need to be carefully considered. With conventional fuels, this is a simple calculation of additional fuel that needs to be uploaded to accommodate a diversion and hold. The calculation will necessarily be different for an all-electric aircraft and will need to address the need for reserve energy and an accurate flight planning in advance. This issue is exacerbated by the initial short range and potential lack of suitable alternate diversion airports.

3. **CONCLUSION**

3.1 A number of battery-powered, all-electric aeroplanes are in development at the time of writing, though all have limited payload and range capabilities due to the energy density of batteries versus conventional fuels.

3.2 These limited capabilities mean that, until a breakthrough in battery technology is made, operations and sizing of aircraft will remain well below the capabilities of current regional aircraft types. However, it is possible, and even likely, that some of these aircraft will operate cross-border, whether as commuter aircraft or as small cargo aircraft.

3.3 In combination with the need to ensure global compatibility of the product with the airport infrastructure and the need to ensure that the management of these aircraft is common across aerodromes globally, it is desirable that ICAO continues to work with the industry to assess any necessary adaptation to Standards and Recommended Practices (SARPs) in a timely way to facilitate introduction of these new propulsion and aircraft types, while maintaining safety and securing continued, seamless operations.

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