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Agenda Item 2: Timely and safe use of new technologies
2.1: Evolving aircraft technologies contributing to LTAG

THE STATE OF THE ART OF HYBRID PROPULSION SYSTEMS

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

EXECUTIVE SUMMARY

Hybrid power systems for civil aeroplanes have the potential to offer significant CO2 and other emissions savings. 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 “Hybrid Propulsion”.

1.2 The principle of hybrid propulsion is not especially new, and has been used for some time in the motor industry. However, the motor industry has transitioned towards the development of all-electric vehicles using technologies that still pose a significant challenge to the aerospace industry. For those reasons, explored more fully below, it is envisaged that hybrid propulsion systems have greater potential for short-haul travel.

1.3 However, the use of hybrid propulsion systems is likely to require additional work in the realm of standard setting to ensure consistent, safe operation within the air transport infrastructure.

2. DISCUSSION

2.1 As mentioned above, all-electric flight is likely to be subject to limitations caused by the energy density of currently-available and foreseen battery technologies. The weight of the batteries compared to the flight endurance that they can deliver means that electric aircraft are likely to remain relatively small with limited payload and range in the short term. Consequently airframe and engine manufacturers have been exploring technologies that can significantly reduce CO_2 (and other) emissions while preserving payload/range capability of larger, regional aircraft.

2.2 The concept of hybrid power is not new. Railway locomotives have been using diesel engines to power electric traction motors for around a century, and the motor industry began introducing hybrid cars in increasing numbers since the early 2000s. Aircraft manufacturers believe that potential exists to transfer such technology to civil operations that are currently performed by turboprops and regional jets.

2.3 Although the concepts differ in detail, all use a conventional engine, which may be either a small gas turbine or a large reciprocating engine, in combination with an electrical power source such as batteries or a hydrogen fuel cell. Most require a turbogenerator that connects the two sources of power either directly to a propeller, or interconnects the two sources of power, although other concepts have been envisaged as described later.

2.4 For subsonic aeroplanes, the highest power is always needed during take-off and climb, with a relatively low power setting being used during the cruise. Current engine designs are sized to provide continued take-off power and climb in the case of one engine becoming inoperative. Different concepts are designed to overcome different challenges in different phases of flight. These can be largely grouped as follows:

a) power ‘boost’ during take-off and climb (electrical power used to increase take-off and climb thrust); and

b) power reduction via partial conventional engine during cruise.

2.5 In the first case, providing a power boost during take-off, electric motors are used to increase the available power only during take-off, allowing the conventional engines to be sized according to the cruise need and not “oversized” for the take-off case. Manufacturers of such concepts claim that this can reduce mission fuel burn, and therefore CO_2 emissions, by around 30 per cent.

2.6 In the second case, the conventional engines remain sized for the take-off case as today, but during straight and level flight, or cruise climb, one conventional engine is shut down. The remaining engine both provides thrust and is used to generate electricity via a turbogenerator, which in turn drives an electric motor producing thrust for the second engine.

2.7 A third, novel, approach for a single-engine aircraft is to use the engine to both drive the propeller and to provide electrical power for smaller propellers driven by electric motors distributed across the leading edge of the wing – the so-called ‘distributed fan’ concept. In this case, the distributed fans accelerate air across the top surface of the wing during take-off substantially increasing lift. This gives the advantage of being able to have a shorter wingspan, reducing drag during all flight phases.

2.8 Another common concept across all of the applications is the ability of the conventional engine to recharge batteries during flight. This would, in some cases, make the aircraft independent of ground-based charging infrastructure.

2.9 Some concepts have the added advantage that the energy stored in the batteries can also be used to power electric motors on the undercarriage, making taxi-out and taxi-in electrically powered. This has the advantage of reducing ground noise and ground emissions, although gas turbine powered aircraft will still need sufficient time after engine start to warm up the engines prior to taking off and after landing to cool down the engines prior to shutting them down.

2.10 In all of these concepts, manufacturers have had to deal with a host of technological challenges not previously experienced in the field of aeronautics. Firstly, the need to consistently generate or store the energy for around 1 MW of electrical power. Secondly distributing that power requires new wiring technology to transmit 500V-800V around the aircraft, with an adequate shielding. Smooth power transfer during flight and reliable turbogenerators are new requirements not faced before.

2.11 Airports will also need to take account of the infrastructure needed to support these aeroplanes and their technologies. Although most can recharge their own batteries, most 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. For those concepts that use hydrogen fuel cells in place of batteries, the storage, distribution and safe handling of hydrogen will be needed. Ramp space to accommodate the additional battery or hydrogen servicing vehicles, including any increased safety distances, will also be required.

2.12 Emergency personnel will need to be equipped and trained to handle battery-fires and other battery-related emergencies (e.g. leakage in case of aircraft damage); similar training will be needed in the case of hydrogen fuel cell use.

2.13 Engine start up procedures are also likely to be different, and an engine run-up or warm-up/cool down area for aircraft that have taxied under their own electrical power may be required.

2.14 There may also be impacts on the take-off and climb phases of flight in the event of a loss of electrical power for those concepts that use electricity as a boost. Standards will need to be developed to ensure an approach at least consistent with those in force today, including for the turbogenerators and power distribution system reliability.

2.15 Consequently, as the competent international standard setting body for international aviation, the industry looks at ICAO for the timely development of Standards and Recommended Practices (SARPs) that allow for the safe introduction and operation of new hybrid-powered concepts.

3. **CONCLUSION**

3.1 All of the concepts mentioned above are in various degrees of production and testing, although it is likely to be into the next decade before fleet readiness. Many of the engines have already been tested in the laboratory; some are currently being installed on aircraft ready for flight; and some of the propulsion systems are already in flight test. There is a high level of certainty, therefore, that hybrid aircraft in one form or another will enter the marketplace by the mid-2030s.

3.2 These power systems do have some significant differences, no matter the concept, from a conventionally powered aircraft. They have additional levels of complexity, but they do offer substantial fuel burn and emissions savings, and many offer this not just during the airborne phases but can also improve noise and local air quality around airports.

3.3 As such, it is important for the industry to work closely in collaboration with ICAO to ensure that SARPs are developed in a timely manner to facilitate introduction of these new propulsion and aircraft types, all while maintain safety and securing continued, seamless operations.

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