Study of Hybrid Electric Propulsion for a Radical Aircraft Concept

03/02/2015

**Auteurs** : G. Barraud, M. Thomas, N. Charr, C. Nespoulous, H. Smaoui

**Publication** MEA 2015 More Electric Aircraft

**OAI** : oai:www.see.asso.fr:10638:20091

**DOI** :

- Document accessible sous conditions - vous devez vous [connecter](#) ou vous [enregistrer](#) pour accéder à ou acquérir ce document.
- Accès libre pour les ayants-droit

### Abstract

### Collection

- Study of Hybrid Electric Propulsion for a Radical Aircraft Concept
- G. Barraud, M. Thomas, N. Charr, C. Nespoulous, H. Smaoui

- Document accessible sous conditions - vous devez vous [connecter](#) ou vous [enregistrer](#) pour accéder à ou acquérir ce document.
- Accès libre pour les ayants-droit

### Authors
G. Barraud
Study of Hybrid Electric Propulsion for a Radical Aircraft Concept

M. Thomas
Study of Hybrid Electric Propulsion for a Radical Aircraft Concept

N. Charr
Study of Hybrid Electric Propulsion for a Radical Aircraft Concept

C. Nespoulous
Study of Hybrid Electric Propulsion for a Radical Aircraft Concept

H. Smaoui
Study of Hybrid Electric Propulsion for a Radical Aircraft Concept

Metrics

Downloaded: 7
Viewed: 8
Size: 128.78 KB
Type: application/pdf
URI: bitcache://e621921b6cc18baa3e6dbc70506252278dd4e35c

License

La SEE (Société de l'Electricité, de l'Electronique et des Technologies de l'Information et de la Communication – Association reconnue d’utilité publique, régie par la loi du 1er juillet 1901) met à la disposition de ses adhérents et des abonnés à ses publications, un ensemble de documents numériques accessibles à partir de son portail des publications. Ces documents incluent notamment les articles des revues REE, 3 EI et e-STA disponibles sous forme numérique ainsi que des publications additionnelles regroupées dans l’espace eREE. Les présentes conditions précisent les conditions de diffusion et d’utilisation de ces documents et des informations qu’ils contiennent. L’accès à ces documents, qu’il se fasse de façon gratuite ou dans le cadre d’abonnements ou d’achats faits à titre onéreux, implique l’acceptation sans restriction de ces dispositions.

Droits de propriété et de diffusion des contenus téléchargés sur le portail des publications

Les contenus rendus accessibles sur le portail des publications sont, en règle générale, protégés
par le droit d'auteur. En tant que producteur, et le cas échéant d’auteur, des informations rassemblées dans les contenus accessibles par ce portail, SEE se réserve l’exclusivité des droits de copie et de diffusion de tout ou partie de ces contenus.

Les contenus sont rendus accessibles à titre individuel, pour les besoins de la personne en détentrant des droits d’accès en cours de validité. Aussi, la modification, la reproduction et/ou la diffusion via Internet ou le Web, intranet, extranet ou toute autre forme numérique ou imprimée, de tout ou partie des contenus téléchargés sont interdites. Une tolérance est consentie quant à la reproduction d’extraits limités de ces contenus, dans le cadre de travaux ou d’activités auxquels ils sont utiles, à la condition que l’origine de ces reproductions partielles soit mentionnée de façon lisible et sans ambiguïté. Figureront en particulier : la REE (ou toute autre revue accessible sur le portail) en tant que la source, la référence de la publication et le nom de l’auteur (s’il figure dans la revue).
Ces dispositions s’appliquent également aux figures, illustrations, logos ou images.

**Publication externe des contenus du portail des publications**

Tout extrait des contenus du portail destiné à être utilisé dans des publicités, des communiqués de presse ou du matériel de promotion nécessite un accord préalable écrit de la SEE. Une version préliminaire du document proposé contenant ces extraits doit accompagner chacune de ces demandes. SEE se réserve le droit de refuser un tel usage externe pour quelque raison que ce soit.

**Responsabilités**

La SEE apporte tout le soin possible à la préparation des informations délivrées dans les contenus produits. Cependant elle ne peut être tenue pour responsable d’aucune perte ou frais qui pourrait résulter d'imprécisions, d'inexactitudes, d'erreurs ou de possibles omissions portant sur des informations publiées, ni des résultats obtenus par l'utilisation et la pratique des informations délivrées.

**Utilisation des informations recueillies lors du téléchargement de contenu**

Le portail des publications est susceptible d'utiliser des « cookies » afin notamment de permettre l'utilisation de paniers d'achat et de personnaliser les parcours sur le site. SEE se réserve la possibilité d'utiliser les informations recueillies lors des téléchargements pour ses besoins internes et notamment pour l'amélioration de ses services, sans qu’elles puissent être cédées à des partenaires commerciaux. Conformément à la loi "informatique et libertés" du 6 janvier 1978, chaque utilisateur du portail dispose d’un droit d’accès et de rectification aux informations qui le concernent. Pour exercer ce droit, les utilisateurs doivent s’adresser à SEE – 17 rue de l’amiral Hamelin – 75783 Paris Cedex 16, par simple lettre ou en utilisant le formulaire de contact disponible sur son site.

Paris, le 28 avril 2013

---

**Sponsors**

**Organizers**
Study of Hybrid Electric Propulsion for a Radical Aircraft Concept G. Barraud (1), M. Thomas (1), N. Charr (2), C. Nespoulous (2), H. Smaoui (2) 1: Airbus Operation SAS, 316 Route de Bayonne, 31060, Toulouse, matthieu.thomas@airbus.com 2: Airbus Group Innovations, charles.nespoulous@airbus.com

Abstract This paper presents performance perspectives associated with the use of a hybrid electric propulsion system for a radical aircraft concept. First, an overview of hybrid concepts is given; and a process to define and evaluate hybrid architectures is presented. Hybridization benefits are then assessed on a radical aircraft concept for a technology level beyond 2030. Lastly, the main challenges of hybrid propulsion are outlined. Airbus and Airbus Group Innovations,
together with a network of cooperation partners, will take up these challenges in the frame of the European Research Program Clean Sky 2, in order to make hybrid propulsion a realistic and differentiating concept. Introduction Propulsion system innovations have been a key driver of aeronautic evolution. The increase of propulsion performance and efficiency has enabled aircrafts to travel at higher speeds over longer ranges while carrying larger payloads. Today the improvement of conventional engine technologies is reaching an asymptote, while future demands on the air transport systems still dictate that aircraft should be less polluting, less noisy and more fuel efficient. In this context, hybrid architectures offer the opportunity to transform in the long term the landscape of aircraft propulsion and furthermore enable new aircraft configurations. However, the feasibility of hybrid architectures has to be established and the improvement in aircraft performance has still to be demonstrated. This paper aims to assess the potential energy saving of a radical hybrid aircraft concept for a technology level beyond 2030. Fig 1 : An example of radical hybrid aircraft concept (E-Thrust, Airbus Group Innovations). Hybrid aircraft definition What is a hybrid aircraft? A hybrid aircraft is an aircraft that uses more than one type of energy source and/or energy flow for propulsion means. Aircraft propulsion is indeed currently limited to kerosene and mechanical transmissions. Combining different energy sources or flows gives additional degrees of freedom to improve the overall aircraft performance, limit the use of non-renewable fossil resources and reduce the aircraft environmental footprint. Today, hybrid technology has mainly been applied to ground-based transports, cars, busses and trains but also ships. While hybrid vehicles are now entering the market in increasing numbers, the power and energy requirements (several mega-Watts) for airborne applications still pose a big challenge. Due to this very high power and energy need, the main energy source of hybrid aircraft concepts will likely remain kerosene. The selection of the secondary energy source is more open, but generally electric hybrid architectures are designed using batteries, fuel cells or solar energy. Other types of hybridization with diesel, biofuel or natural gas are less common. Hybridization enables to combine the efficiency and clean power of electrical machines with the extended range and power capacity of gas turbine. Active research is ongoing on hybrid technologies by academic institutes, research labs and major aeronautic actors. In particular, significant research effort needs to be raised on the size, weight and efficiency of battery storage systems, power electronics, and on electric machines. One flying demonstration of a hybrid architecture has already been performed. The DA36 E-Star, a two-seat, low-wing motor-glider powered by a serial hybrid electric drive developed by Siemens, Airbus Group Innovations and Diamond, has already proven the potential of such technology carrying two people over 485 NM with 25 percent less fuel. We are obviously still far from civil transport aircrafts but technology improvements that can be observed at a lower scale or in other industries lead us to consider the use of hybrid propulsion systems on the next generations of aircrafts beyond 2030. Fig 2 : DA36 E-Star Hybrid aircraft propulsion architectures Many variants of hybrid propulsion system architectures exist but most derive from the three following categories: series, parallel and series-parallel (Fig. 3). As in the automotive industry what differentiates parallel from series architectures is that in the first case there is a mechanical link between the gas turbine and the fan or the propeller while in the latter case there is none. Parallel-Series architectures combine both mechanical and electrical transmissions between gas turbines and fans, allowing combining or switching from one to another depending on the flight phase. Fig. 3: Serial, Parallel and Series-Parallel hybrid architectures. Apart from physical considerations, it is worth to mention that a hybrid aircraft is characterized by its degree of hybridization, i.e. the ratio between the power of the kerosene-fuelled gas turbine and the power of the electric motor used to propel the aircraft. Multiple degrees of hybridization are possible and vary during the aircraft operations: this constitutes the energy management strategy. Process to define and evaluate hybrid architectures The integration of new technology bricks hybrid propulsion leads to a new level of complexity that must be managed from the early design phases of the aircraft. Following the pattern of More Electrical Aircraft studies dedicated to non-propulsive systems, this integration is done at different levels (Fig. 4), either in sequence or in an integrated way: • an energy management loop • a sizing loop dedicated to the components of the architecture (using for instance AMESim) • a synthetic loop dedicated to the aircraft mission profile These different processes operate regarding to environmental constraints, either operational (conditions and flight profile) or functional (requirements due to failure cases). A final overall design loop (at aircraft level) can take into account the so-called “snowball” effects on the weight and performance of the aircraft induced by mass, drag and performance deviations at systems level. Fig. 4: Processes to evaluate hybrid aircraft architectures Description of the energy management strategy Because of its high design flexibility, a series architecture was considered for our radical aircraft concept (Fig. 5). It is composed of a main gas turbine and a battery pack that supply electrical machines, each driving a single fan. Batteries provide energy needs during ground phases but may also supply extra power during high power demand phases (take-off and climb). The gas turbine is operated on a single rating during the overall mission, leading to a more efficient system. Additionally, fans have the capability to windmill and produce electricity to re-charge the batteries during descent phases. The Power Management And Distribution (PMAD) system controls the energy flows between the various components as a function of flight conditions and battery state of charge. Fig. 5: Hybrid propulsion system of a radical aircraft concept. From state of the art analysis, the component characteristics of the hybrid propulsion chain have been derived for a technology level beyond 2030 and used as input. Results and discussions In this study, we considered as invariant boundary conditions aircraft range and time to climb, which allowed comparing the fuel burn, the energy consumption and the max Take-Off Weight (MTOW) of a conventional and hybrid radical aircraft concept. In the first steps of the study, the hybrid radical aircraft ended up being heavier than the conventional aircraft because of the installed weight of electric transmissions and batteries. However the energy management strategy allows improving the overall efficiency of the propulsion chain, which widely counterbalanced the aircraft weight penalty. Up to 20% of energy saving could potentially be reached thanks to the use of a high efficient electric power chain (above 90%) , and thanks to the operation of the gas turbine at its optimal efficiency during the whole flight, which is far from being the case on a conventional aircraft, notably in idle phases. A significant part of the savings is performed on ground. The use of the batteries instead of the conventional auxiliary power unit and gas turbines leads to immediate fuel
savings. Logically, the relative hybridization benefits are higher for short range operations. Finally the savings will depend on the aircraft mission profile and on the use of a smart energy management strategy. The aircraft system architecture as a whole has probably to be revisited in order to take the maximum benefits from the hybridization. In this sense, the replacement of pneumatic and hydraulic networks by a full-electrical network as proposed on the More Electric Aircraft will likely be an enabler of hybrid aircraft concepts. Fig. 5: range of fuel and energy savings foreseen for a hybrid radical concept Conclusion

Constrained by current available technologies, hybrid and “full-electric” airplanes are today limited to short range ultra-light aircraft (1-4 seats). To close the gap to commercial aviation, substantial improvements have to be done. Fig 6: full-electric ultra-light aircrafts (eGenius, eFan) First, at technological level, the batteries will have to be able to reach higher specific energy and power values, and the power electronics will have to sustain very high voltage levels while increasing their efficiency so as to limit the heat losses (see Table 1). Airbus together with Airbus Group Innovations will rely on a network of cooperation partners, in the frame of the European Research Program Clean Sky 2, to make hybrid propulsion a realistic and differentiating concept. Significant technological locks will need to be overcome with the help of partners and suppliers especially regarding the operation at high altitudes of high power and high voltage electric components

Component Target characteristics beyond 2030

<table>
<thead>
<tr>
<th>Component</th>
<th>Target characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Speed Electric machines</td>
<td>(n x 10000rpm) 10 to 15kW/kg Above 98% efficiency</td>
</tr>
<tr>
<td>High-efficient Power electronics</td>
<td>15 to 20 kW/kg, above 99% efficiency</td>
</tr>
<tr>
<td>High-Energy Battery Systems</td>
<td>500 to 700Wh/g</td>
</tr>
</tbody>
</table>

Table 1: Components sizing parameters

The aircraft platform itself will also have to evolve. New engine integration configurations, new aircraft system architectures and even new aircraft operation modes will be required so as to make full use of the new degrees of freedom offered by the hybrid architectures.

https://www.see.asso.fr/en/node/20091/landing