Green Regional Aircraft – The European Clean Sky Program aims for greener Aeronautics

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ABSTRACT

Environmental friendliness of air traffic is of significant importance due to steadily rising passenger counts worldwide. On the one hand, air transport is a keystone to further economic growth but on the other it is facing all the global economic and ecological issues of today.

The scope of aeronautic RTD objectives and the scale of necessary resources required setting up an industry-driven long term Public Private Partnerships (PPP) in the form of a Joint Technology Initiative (JTI). 'Clean Sky' JTI [1] works towards the objectives and targets defined in the Strategic Research Agenda (SRA) of the Advisory Council for Aeronautics Research in Europe (ACARE) [2] and its updates. With Clean Sky as an innovative European program aiming at massively lower the impacts of air transport on the environment, the established PPP collaborates towards ambitious goals as

- Less fuel consumption,
- Reduced emissions,
- Greener design, production, and maintenance and
- Faster introduction of innovative technologies into market.

Clean Sky will deliver demonstrators in all segments of civil air transport, grouped into six technological areas called 'Integrated Technology Demonstrators' (ITD). Smart structures and integrated advanced low-noise solutions, innovative concepts for active flow and load control as well as green design, manufacture, maintenance and recycling for airframe and systems will be demonstrated.

Fraunhofer Germany (FhG) is one of the managing organizations of the 'Clean Sky' program. The paper gives a brief introduction to Clean Sky and will focus on innovative concepts for active flow and load control offered by FhG. The new technologies applied will substantially increase the high lift capabilities of the wing during take off and landing and decrease annoyance due to noise at the same time.

Keywords: noise reduction, lower emissions, reduced fuel consumption, greener design, strategic aeronautical research

1 SCOPE AND STRUCTURE OF CLEAN SKY

Clean Sky, born in 2008 is the most ambitious aeronautical research program ever launched in Europe with its mission to develop breakthrough technologies to significantly increase the environmental performances of airplanes and air transport, resulting in less noisy and more fuel efficient aircraft [1]. The Clean Sky JTI represents a unique PPP between the European Commission and the aeronautical industry, managed by the Clean Sky Joint Undertaking (CSJU), which is an administratively autonomous holding type enterprise, until end of 2017. The Founding Members of the CSJU are the European Union, represented by the European Commission (EC), and 12 ITD leaders and their Associates [3]. The Founding Members and Associates of Clean Sky in addition to the European Union represent 86 organizations in 16 countries, among which 54 are industries, including 20 SMEs, 15 Research Centers, and 17 Universities.

Reducing the environmental impact of aviation has high priority according to the ACARE SRA. Ambitious objectives with aims of achieving substantial technological changes by 2020 (with reference to year 2000) are under consideration by the CSJU accordingly:

- 50% reduction of CO_2 emissions through drastic reduction of fuel consumption,
- 80% reduction of NO_x emissions,
- 50% reduction of external noise,
- ensuring a 'green' product life cycle, making substantial progress in reducing the impact of manufacturing, maintenance and disposal of aircraft and related products on the environment

Many technical areas in aviation are speeded up by the environmental challenge. Following the vision, aircrafts are cleaner and quieter by 2020, and the positive contribution of the aeronautics sector to sustainment and improvement of our environmental conditions is widely understood and appreciated. The implementation of innovative, environmentally friendly technologies in all segments of civil air transport, including large commercial aircraft, regional aircraft, helicopters, and in all supporting technologies such as engines, systems and materials' life cycle and validation of results in a multidisciplinary

approach is leading to full-scale ground and flight demonstrators, giving the industry greener, more innovative aviation products.

The program allows the implementation of ambitious and complex activities, including the validation of technologies at a high level of readiness and is now about reaching its steady-state operation towards system-level demonstrators of green technologies for all kinds of aircraft. It generates enormous socio-economic impact while implying aircraft industry and opening access to SMEs and to new member states. Going beyond conventional collaborative projects, it puts together a majority of aeronautical primes, tiers one, research centers and hundreds of partners. Stable new links are being created between universities, SMEs and integrators in longer term, comprehensive and results-focused collaborations.

Through calls for proposals (CfP) every 3 or 4 months as well as subcontractors selected through Calls for Tender (CfT), the CSJU is involving a steadily increasing number of partners. Currently, close to 400 stakeholders are engaged in Clean Sky in total, with still growing tendency. In addition, a large multiplier effect is expected by complementary and coordinated co-operation with SESAR JTI for the aircraft trajectory and mission and complementing national programs.

Size and scale of JTIs require the mobilization and the management of very substantial public and private investments and of large human resources. Public funding therefore has been made available via European Commission (EC) and allocated to Clean Sky with a total amount of € 800 million. The contribution of private partners will be another € 800 million out of their budgets in total. € 400 million of the EC contribution shall be allocated to the leaders of the ITDs: Agusta Westland, Airbus, Alenia Aeronautica, Dassault Aviation, EADS-CASA, Eurocopter, Fraunhofer, Liebherr-Aerospace, Rolls-Royce, Saab AB, Safran and Thales and € 200 million to Associates. € 200 million shall be allocated to Partners selected by way of competitive CfPs. The Clean Sky JTI is thereby stimulating industrial engagement in studying and minimizing the impact of the aeronautic transport system (ATS) on the global environment via a holistic approach for research. It is doubtable that without a dedicated program such a set of common objectives would have been agreed by all stakeholders, translated into the different aircraft types, addressed through a common and stable program with cross-links and common rules, evaluated and monitored through dedicated tools [4]. The aircraft technologies themselves have still a significant potential for innovation and progress would have been much slower without such technology demonstration effort undertaken within the next years.

The CSJU activities are organized in six technology areas – 'Integrated Technology Demonstrators' (ITDs):
Vehicle ITDs:

- Smart Fixed Wing Aircraft (SFWA)
- Green Regional Aircraft (GRA)
- Green Rotorcraft (GRC)

Transverse ITDs:

- Systems for Green Operations (SGO)
- Sustainable and Green Engine (SAGE)

and an ITD that is transverse to all ITDs:

- EcoDesign (ED)

Technology Evaluator (TE):

- In addition, 2% of the EC contribution will be devoted to the Technology Evaluator with the aim of assessing environmental impact and benefits of technologies arising from individual ITDs.

Smart Fixed-Wing Aircraft (SFWA) ITD aims to develop an all new wing design that makes use of passive and active flow and load control technologies and will help to reduce the drag of the wing in cruise as a means for reducing fuel burn and emissions by up to 20% and noise by 5 to 10dB. The objective of the Green regional aircraft (GRA) ITD is to validate and demonstrate technologies best fitting the environmental goals set for the regional aircraft entering the market in the following years. The ECO Design ITD is taking the three distinctive phases of the total aircraft life cycle into consideration: aircraft design & production, aircraft use & maintenance, aircraft withdrawal. The Systems for green operation (SGO) ITD will improve aircraft operation through the management of aircraft energy and the management of mission and trajectory. Full engines or core ground demonstrators will be the output of the Sustainable and Green Engines (SAGE) ITD while modified existing rotorcraft will be that of the Green Rotorcraft (GRC) ITD. Finally, the technological innovations of all ITDs will be assessed regarding their economic and environmental effects. This will be done by the Technology Evaluator group. The Technology Evaluator acts as an essential element of the Clean Sky as it independently verifies the achievements against the targets identified. TE monitors ITDs progress along Clean Sky duration for JU stakeholders, internal and external entities. TE consistently assesses the merit of complementary R&D activities performed in ITDs with regards to ACARE environmental objectives, bringing global air traffic system view. TE helps identifying interdependencies of impacts and provides elements of guidance and justification for decision making within Clean Sky, to maximize JTI synergy effects.

2 THE GREEN REGIONAL AIRCRAFT ITD (GRA)

In 2020, globally around 50% of flights will be operated with regional aircraft (45% today). Thus, the objective of the Green Regional Aircraft (GRA) ITD is to validate and demonstrate the technologies best fitting the pollution and noise reduction goals set for the regional aircraft that will enter the market in the 2020s. The ITD will deliver:

- Low weight technical solutions using advanced structures and materials

- Configurations for low aerodynamic noise
- The optimized integration of technologies developed in other ITDs.

Most promising "mainstream" technologies (Low Weight and Low Noise Configurations) are being developed according to the requirement of greening future regional aircraft. Using a multidisciplinary approach, technical solutions from mainstream technologies and from other technical domains of Clean Sky are integrated into the demonstrators of the Green Regional Aircraft. The technologies and the solutions developed and matured in the GRA ITD will be demonstrated to gather final confidence on their applicability to future aircraft programs. Full scale advanced structural assemblies, low noise advanced aerodynamics, integration of advanced systems and avionics will be tested on ground and in flight, along with large-scale wind tunnel tests of advanced aircraft configurations.

The GRA ITD concentrates on low weight (LWC) and low noise (LNC) for regional aircraft up to 50 tons, including all-electric technologies. Structural health monitoring (SHM) concepts based on fibre optical Bragg grating (FOBG), Acoustic Emission (AE) and Ultrasonics (AU), wireless communication, thermoset and nano-reinforced composite materials as well as laser beam welding represent the core of Fraunhofer involvement in LWC. Technologies that shield or lower the noise produced by conventional aircraft or engines, such as low noise component design, landing gear fairing, and advanced acoustic panels are being developed.

For low noise purposes in LNC, simulations will comprise computational fluid dynamics (CFD) and computational aero acoustics (CAA) as prediction tools for noise. Advanced leading edge design, landing gear geometry and kinematic will be developed and tested in the wind tunnel. Furthermore, the new technologies imply the need for appropriate and advanced measuring techniques and equipment for use in boundary layer and acoustic measurement even under cryogenic conditions.

3 ACTIVE FLOW CONTROL FOR HIGH LIFT CONFIGURATIONS

The GRA ITD will include all disciplines traditionally involved in aircraft design: flight physics, structure and systems [1]. New high-lift systems designed for high climb rates at take-off and quiet drag generation at approach enable aircraft to perform steep take-off and approach without effecting cruise drag with slatless configurations additionally reducing noise. Blown flaps enhance high-lift performance additionally.

Active flow control on aircraft wings is proven to be capable of enhancing lift and delaying separation. Suction or continuous blowing can be applied as well as pulsed blowing feeding rapidly switching valves with pressurized air (Fig. 1, courtesy NLC). Synthetic jet actuators (SJA) have the advantage not to require pressurized air, they generate zero net flux locally.

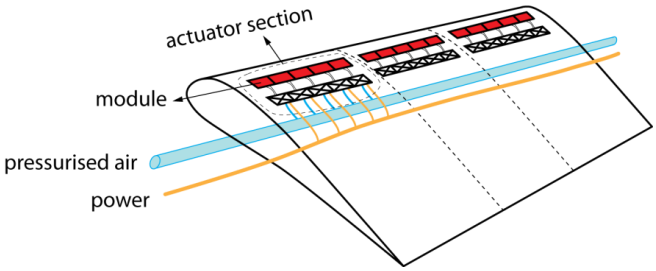

Fig. 1: Active flow control by blowing on a flap

The design of several SJA flow control systems on reference aircraft showed that the power generation subsystem, the actuators and the fuel are dominant elements on the systems weight, depending on the application being considered. The flap case presented the lowest weight and power penalties, making it the most appealing application with all system's weight resulting in a fraction of a conventional passive flow control system and all system's power requirements within the limit of a typical APU power rating [5]. For cruise applications like buffeting control, the weight of both, the power transmission and storage elements, increase by ≈600% in comparison to the Flap/Slat take off and landing application.

It is evident from previous investigations, that synthetic jets can be used to influence or interact with the boundary layer and to avoid or control separation. Attempts are described which observe and explain the origin and the influence of jets on the boundary layer as well as on descriptions and models that can be used to develop and to optimize actuators which generate these jets. The performance is depending on three major parameters:

- Actuation frequency
- Exit velocity
- Mass flow

The transducer (piezo-membrane) geometry is influencing the actuation frequency and in combination with the Helmholtz resonator the exit velocity. For high performance the membrane itself has to be optimized. Shaping of the chamber and the orifice is very important for high exit velocities (Fig. 2).

The piezoelectric synthetic jet actuators must have sufficient velocity output to produce strong longitudinal vortices if they are to be effective for flow control. The effectiveness of synthetic jets strongly depends on the forcing frequency. For low power consumption, they have to be driven in resonance, which results in serious reliability concerns for the membrane and clamping. Reduced models have been employed to simulate the coupled mechanical fluidic behavior. Aim of the development of reduced models is to have a tool to pre-calculate a design to fit the requirements for different applications.

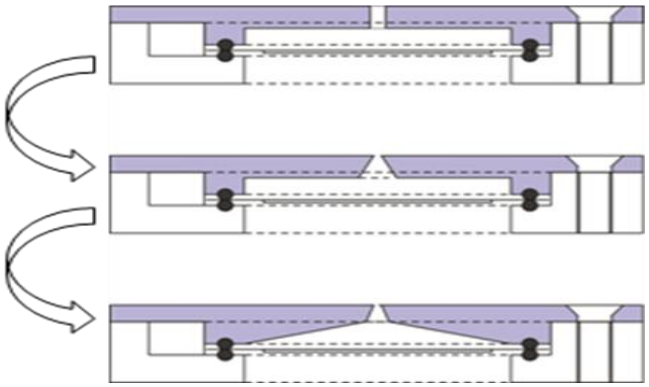

Fig. 2: Optimization process for increasing the efficiency of SJA – orifice and pressure chamber shaping

The novel modeling method for the design of a circular piezoelectric unimorph actuator, the Combined Simulation (CS), connects Lumped Element (LE) and Finite Element (FE) Methods at user level [6]. Thus, it is possible to calculate the electromechanical subsystem with FEM to extract lumped parameters out of it, which can be used in a LEM. The acoustical system can be modeled by LEM accurately.

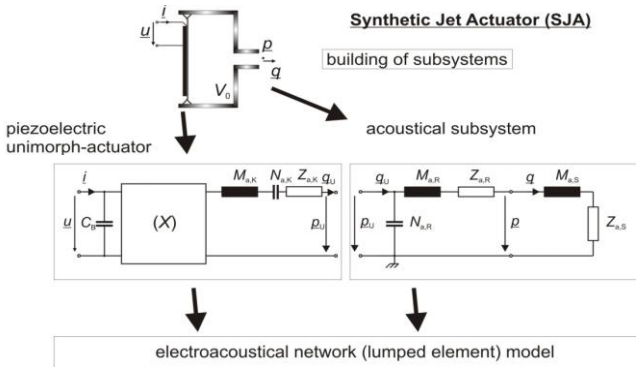

Fig 3: Combined Simulation of a SJA modeled

This method (Fig. 3) has been used for an accurate description and optimization of SJAs. To verify the model and its adequacy for the simulation and optimization of SJAs, they were compared with measurement results and have been proven to yield adequate behavior. From the optimization process, a power optimized double membrane SJA has been derived as shown in Fig. 4.

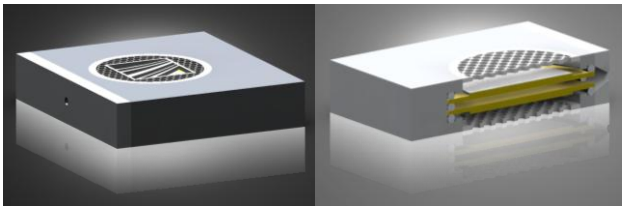

Fig 4: Schematic of the new double membrane actuator

4 SUMMARY AND OUTLOOK

Clean Sky, a Public Private Partnership between the European Commission and the Aeronautical Industry, has been established to bring significant step changes regarding the environmental impact of aviation according to ACARE's vision 2020. The advanced technology demonstrators of the six ITDs are representing cleaner solutions tested on full scale, thus contributing significantly to reducing the environmental footprint of aviation. Clean Sky is definitely not the end of the story, new targets towards 2050 are: 75% of CO_2 reduction, 65% of noise reduction etc. One out of the variety of means that have to be addressed is active flow control, which has been proven to be most effective for high lift applications. To optimize weight penalties for fluidic actuators, SJA technology has been developed towards efficient devices.

ACKNOWLEDGMENT

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