ACFA 2020 Report Summary

Project ID: 213321
Funded under: FP7-TRANSPORT
Country: Germany

Final Report Summary - ACFA 2020 (Active control for flexible 2020 aircraft)

Executive summary:

ACFA 2020 (please see [http://www.acfa2020.eu](http://www.acfa2020.eu) online) deals with innovative active control concepts for ultra efficient 2020 aircraft configurations like the Blended wing body (BWB) aircraft. The objective of the active control concepts investigated and designed in ACFA 2020 are an ambitious load reduction on BWB type aircraft as well as improved ride comfort and handling qualities. Main focus lays at the application of new promising active control concepts like modern robust control design techniques, adaptive feed-forward control and neural network control. In a first step control concepts were designed for the large flying wing aircraft designed in the Very Efficient Large Aircraft (VELA) and New Aircraft Concepts Research (NACRE) project, but the main use case is a newly designed ultra efficient 450 passenger aircraft. For this 450 passenger aircraft design a flying wing and an ultra wide body fuselage aircraft with carry-through wing box have been compared. Due to significant better fuel efficiency the BWB design has been retained for the further work in the project. Based on the attained loads reduction by active control, the structure of this new 450 passenger aircraft has been resized with the goal of weight saving for further improvement of fuel efficiency.

To summarise, the ACFA 2020 project investigated robust as well as adaptive multi-channel control architectures for loads alleviation, improvement of ride comfort and handling qualities on BWB type aircrafts, as well as the design of a new ultra efficient 450 passenger BWB type aircraft.

BWB type aircraft configurations are seen as the most promising future concept to fulfil the Advisory Council for Aeronautics Research in Europe (ACARE) Flightpath 2050 goals regarding reduced fuel consumption and external noise. Aircraft efficiency can be drastically increased through minimisation of the wetted area and by reduced structural weight. The BWB configuration also offers a great potential for the minimisation of noise signature through integration of the engine over the rear fuselage or in the airframe and also due to the generally higher wing area/weight ratio, which allows for a simplified high-lift system. The structural weight of BWB type aircrafts can be further minimised thanks to the effect of active Multiple-input and multiple-output (MIMO) control developed in ACFA 2020. Therefore ACFA 2020 strongly contributes to meet the ACARE Flightpath 2050 goals.

Project context and objectives:

It is of vital interest for Europe to respond to the challenge of designing a green aircraft in order to cope with the growing world responsibility in regards to environmental protection and to ensure world leadership in the field of aeronautics. The ACARE, whose goal is to develop and implement a strategic approach to European aeronautics research, delivered a Strategic Research Agenda (SRA) in November 2002 and an updated version in March 2005. The SRA is the plan for realising the ‘ACARE vision 2020’, which aims for 50 % reduced fuel consumption and related Carbon dioxide (CO2) emissions per passenger-kilometre and a reduction of external noise by 4-5 dB and by 10 dB per operation in the short and long terms, respectively.
The ACFA 2020 has been designed to serve these goals which can only be achieved through major changes in aircraft configuration. Very promising concepts in regards to improved fuel efficiency are BWB type aircraft configurations. Low fuel consumption is mainly achieved by reduced structural weight and through a minimum wetted area which is significantly lower for BWB type aircrafts compared to other configurations. Exterior noise signature can be reduced by a simplified high-lift system and through the integration of the engines over the rear fuselage or in the airframe. The challenge created by the complex active control system for BWB type aircrafts has been identified, but not yet addressed in the European projects VELA and NACRE. In addition, there is a need for the pre-design of a marketable European flying wing aircraft of smaller size. Therefore the two main challenges taken by the ACFA 2020 project are to provide solutions for the active control system for BWB type aircrafts and to pre-design a new ultraefficient aircraft.

Solutions for active MIMO control for BWB type aircrafts:

Active control systems for the alleviation of structural vibrations as well as of gust and manoeuvre loads have been investigated for conventional aircraft configurations in former research projects and are partly already used in current aircraft. Such active control systems are an important means for the reduction of critical loads which results in lower weight. Moreover an improvement of ride comfort and handling qualities can be achieved which is in particular of high importance for tailless aircraft. BWB type aircraft set new challenges in regards to control design and optimisation, as well as control system architecture. Therefore the high interaction between control and system aspects was also taken into account by ACFA 2020. In order to achieve those objectives the activities were organised in four areas. In work package 1 two aircrafts, a blended wing body and a more classical ultra wide body aircraft were designed and compared. In work package aeroelastic dynamic models for the NACRE flying wing and the new ACFA 2020 blended wing body were generated. The aeroelastic models were reduced in order to make them applicable for the control design tasks in work package 3 dealing with the control design. The focus laid on the application of modern robust control design techniques as well as adaptive control. Finally in work package 4 project results, in particular achieved ride comfort and loads alleviation are assessed and a resizing of the ACFA 2020 aircraft has been performed.

Project results:

The beginning conceptual designs of a 450 passenger BWB and ultra-wide-body aircraft with carry through wingbox have been conducted. The blended wing body aircraft showed about 13 % better fuel efficiency compared to the wide body aircraft with carry through wing box and was used as the main ACFA 2020 configuration.

Dynamic aeroelastic models have been generated for the large NACRE BWB aircraft as well as the ACFA 2020 BWB. The models are parameterised with respect to Mach, dynamic pressure and centre of gravity position. Full order models are reduced to an order appropriate for the control design tasks using modern order reduction techniques. Linear fractional representations (LFR) of the models are used for the application of robust control and Linear parameter varying (LPV) design techniques.

A major goal of the ACFA 2020 project is to investigate and to combine various modern robust control and LPV design techniques as well as adaptive control concepts. A main focus laid on the augmentation of feedback control by feed-forward paths to alleviate the effects of turbulence and gusts. Feed-forward control is also used for pilot commands to alleviate manoeuvre loads and provide at the same time desired handling qualities. Control design for large flexible aircraft and in particular the BWB configuration is a quite challenging task due to numerous objectives and severe constraints which have to be taken simultaneously into account. A large variety of design methods (H-infinity-, H2-optimal control design, H-infinity fixed-order optimisation methods, convex synthesis) and robust and scheduled extensions of these methods have been applied. An adaptive MIMO feed-forward control concept to mitigate turbulence induced vibrations and related loads was validated by a flight test with the DLR Advanced Technologies Testing Aircraft (ATTAS). Information from a flight log sensor at the nose boom is used to compensate structural vibrations caused by turbulences. Two flight test campaigns were performed...
and proved that the predicted performance can be reached under realistic conditions. In addition, neural network adaptive control techniques have been applied to enhance damping of structural modes.

The BWB concept proved to be quite efficient with respect to fuel burn also for medium sized transport aircraft (450 passengers). Compared to a more conventional configuration and application of same engine technology more than 13% less fuel burn has been estimated for the BWB aircraft. In a final step the ACFA 2020 BWB were resized taking into account the achieved loads reduction due to active loads control resulting in additional weight savings of several tons.

To summarise the ACFA 2020 project showed that the BWB concept is quite attractive mainly with respect to fuel burn and that it can be further improved by enhanced active control. Nevertheless there is still a long way to go to bring such an unconventional configuration to reality. In particular the application of an integrated design process, i.e. the simultaneous optimisation of flight characteristics and control for crucial mission profile phases, should lead to significant further improvements.

Potential impact:

Blended wing body type aircraft configurations are considered as the most promising future concept to fulfil the ACARE vision 2020 and Flightpath 2050 goals. Aircraft efficiency can be dramatically increased mainly due to a minimised wetted area. Even it was not assessed in ACFA 2020 the BWB configuration also offers a great potential for exterior noise reduction through integration of the engine over the rear fuselage. The flying wing aircraft is a very promising configuration for the elimination of noise nuisance outside the airport boundary both by day and by night and thus enables future growth in air transport. The structural weight of BWB type aircrafts can be further minimised thanks to the effect of active loads control concepts developed in ACFA 2020. This has been shown for the new 450 passenger ACFA 2020 aircraft configuration. The expected performance superiority of the BWB concept has been confirmed by ACFA 2020 and no show-stopper have emerged. A BWB control community has been established, that should be reinforced in the future. Important topics are the low speed area but also further investigation of BWB sensitivity against gust and best suited control surface layout for gust load alleviation. In order to get a coordinated progress in the BWB knowledge the next step should be also in another direction e.g. pressurised centre body structural design and integrated approaches to optimise loads control and structure in a single step. ACFA 2020 can be therefore considered as a major step forward towards a marketable flying wing.