OVERVIEW OF R&T PROGRAM FFS: ADVANCED COMPOSITE AEROSTRUCTURES

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Keywords: Composites, Structural Bonding, Radome, Unmanned Air Vehicle (UAV), SatCom, Low Observability, 3D Printing

Abstract

The R&T program FFS (german Fortschrittliche Flugzeugstrukturen FFS, engl. Advanced Aerostructures) has been established in 1995 in order to harmonize and steer the R&T activities with respect to advanced composite aerostructures between Airbus Defence & Space, Airbus Group Innovations, German Aerospace Center (DLR Braunschweig and Stuttgart) and Bundeswehr Research Institute for Materials, Fuels and Lubricants (WIWeB) in Erding. With these partners the program started in the 6. phase beginning of 2015.

Within this paper an overview will be given on the four main sub-projects or work packages which cover the following topics: - Structural Bonding incl. demonstration on Eurofighter Airbrake - Advanced multiband radomes for future UAVs - Stealth Design of internal bays - Thin Plies Materials and 3D printing with polymers for spare parts.

1. Introduction

In the middle of the 1990s different R&T master programs have been established at former Daimler Benz Aerospace AG (Military aircraft) in order to coordinate and harmonize the national research activities of the Aerospace Industry with the German Aerospace Center (DLR).

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The R&T master programs covered a wide range of typical aerospace engineering disciplines such as aerodynamics, conceptual design, advanced aerostructures and many other. One of these R&T innovation programs was (and still is) the program "Advanced aerostructures" (or in german Fortschrittliche Flugzeugstrukturen FFS). The project is defined within 3-years time frames, called phases. As illustrated in Figure 1 the project is now in the 6. Phase. The topics, objectives and achievements within this 6. phase ("FFS6") will be highlighted in this paper.

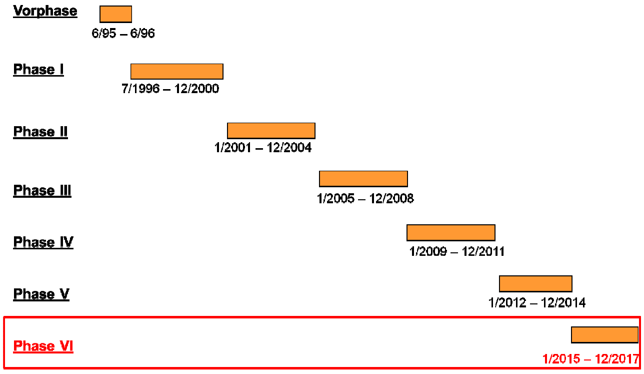

Figure 1. Phases of the R&T program FFS

The partners in FFS6 are Airbus Defence & Space (Military Aircraft), Airbus Group Innovations (AGI), the German Aerospace Center (DLR) and the Bundeswehr Research Institute for Materials, Fuels and Lubricants (WIWeB). Airbus Defence and Space acts as coordinator of the R&T program in this consortium, provides technology development specifications and evaluates technical solutions and innovations for future applications in Airbus Defence and Space products. The Airbus Group Innovation is involved in the process development, while the DLR institutes in Braunschweig and Stuttgart are mainly involved in innovative composite design, new materials and manufacturing technologies. The Bundeswehr institute WIWeB in Erding is involved in structural testing and analytics.

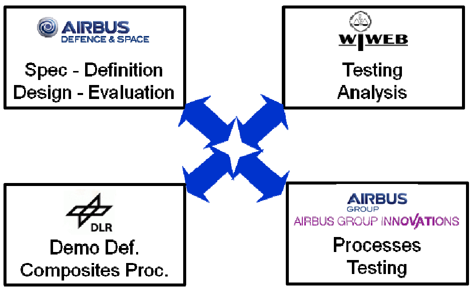

Figure 2. FFS6 partners and contributions

The R&T needs are based on existing as well as on future Airbus DS products of different maturity according to Product Portfolio. FFS6 is therefore addressing the R&T needs from the aerostructures point of view for different platform as shown in Figure 3. The range of aircraft platforms is from Eurofighter Typhoon Midlife Upgrade, to Advanced UAVs of the category MALE (Medium Altitude Long Endurance) and manned or unmanned platforms with very low radar observability. The 4th group of platforms to be supported by advanced structural technologies is the HAPS platform. HAPS stand for High Altitude Pseudo-Satellite and runs exclusively on solar power with batteries charged during daytime for operation at night. It is operating in the stratosphere in an altitude of about 20km above weather and regular air traffic.

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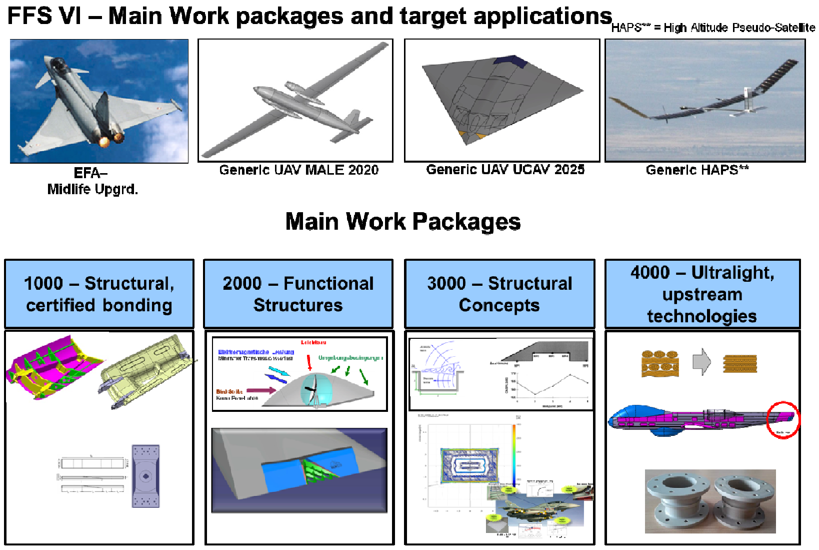

Figure 3. Target applications and Overview of main work packages in FFS6

Based on these aircraft platforms R&T goals and activities have been defined for FFS6 which have been clustered in four main work packages as follows:

- WP1000 – Structural, certified bonding: Structural bonding of composite structures for advanced structural design as well as for structural repairs.
- WP2000 – Functional structures: Advanced multiband, lightweight radome for MALE UAVs and gapless flaps for reduced radar cross section
- WP3000 – Structural Concepts: Integration of large internal bays in blended wing body A/C configurations and Low Observability Materials and Design
- WP4000 – Upstream, Ultralight and Affordable Technologies: New composite materials such as Thin Plies, 3D Printing with Polymers and Structural design studies for affordability for MALE UAV.

In the following chapters 2 – 5 of this paper a more detailed overview will be given on each of the for mentioned main work packages.

2. WP1000 – Structural bonding

Joining technologies play a substantial role for lightweight and affordable composite aerostructures. One of the composite manufacturing technologies in order to achieve lightweight and affordable composite structures is the *Co-curing* manufacturing technology. Different parts or subassemblies are cured together in the autoclave with temperature and pressure. In general large and complex structural parts are manufactured using this technology. However the toolings are in general expensive and very complex. An additional drawback is that process induced flaws or deviations have to be reworked or repaired which is time consuming and expensive, rather than scrap the part. Another possibility of joining composite parts is the so called *Secondary Bonding*. According to this technology smaller and less complex parts are cured separately and bonded after curing in a separate process using a film adhesive or a paste adhesive. The benefits are in terms of reduced the number of complex toolings and therefore costs as well as rather scrap small and cheap components if during the manufacturing deviations should occur. The single parts may also be manufactured using different manufacturing technologies (e.g. pultrusion for profiles) and joined after curing.
According to civil airworthiness certification regulations, which are valid in a very similar way for the future MALE UAVs in order to achieve certification for the UAV to enter non-segregated airspace, secondary bonded composite structures can only be certified today if one demonstrates that a crack stopping feature is able to limit debonding to carry design limit loads until detection. In order to fulfill

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this requirement it is state of the art to apply so called chicken rivets in structural bonded parts. Due to cost as well as due to structural mechanics the main goal is to neglect completely or at least to reduce significantly chicken rivets. A basic condition is to develop and demonstrate robust bonding processes including advanced surface treatment in order to enable the process of adhesion on contamination-free surfaces. Therefore the main goal of the WP1000 – Structural Bonding is to develop robust bonding processes, develop a certification strategy based in the first step on Eurofighter standards based on rivetless bonded structure and demonstrate it including flight testing on one of the Eurofighter instrumented production aircraft (IPA).

After screening of different potential structural components it has been decided to select the Eurofighter Twin Seater (EFA T/S) airbrake (Figure 4) as platform for the structural bonding activities.

Figure 4. EFA T/S with deflected airbrake (which serves as platform for the R&T activities)

The structural concept of the serial part is illustrated in Figure 5. The spars (in V-shape) are co-cured on the outer composite skin in the autoclave. Based on this structural part two derivatives have been defined in the R&T project as follows: The derivative A ("A-Model") and the derivative B ("B-Model"). The main objective for the derivative A is to achieve military certification using only materials qualified in the EFA program and keeping the basic structural concept unmodified in order to maximize re-use of design data from EFA program. The main difference compared to the serial airbrake is to bond the V-shaped spars by secondary bonding instead of cu-curing. Note, that co-curing is not considered bonding by the airworthiness regulations, basically because the most import issue of adhesion and contamination is not the joining mechanism since the resin is not cured.

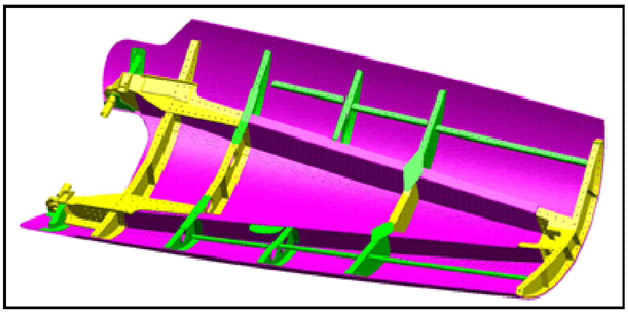

Figure 5. Structural concept of serial EFA T/S airbrake

For the specification and development of the secondary process a film adhesive (EA9695) which is already qualified in the EFA program has been used. The atmospheric plasma technology has been selected as surface treatment method to ensure good adhesion on the composite surface and remove potential contamination. Extensive experimental studies on plasma parameters such as nozzle distance, rate of feed and many other have been performed in order to specify robust process windows. The left hand side of Figure 6 illustrates the V-shaped spars to be (secondary) bonded to the outer skin of the A-Model airbrake. Until end of 2016 it is planned to finish manufacturing including final assembly of the A-Model for the flight demonstrator, so that flight tests on an Eurofighter instrumented production aircraft (IPA) can start in 2017 in Manching.

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The goals of the "B"-model derivative are quite different compared to the ones for the "A"-model. The main objective of the B-model development is to develop advanced and affordable structural concepts using the structural bonding joining technology and a *design-to-cost* approach. As shown on the right hand side of Figure 6 topology optimization techniques have been applied in order to assess different design concepts considering optimum load paths. A bonded 2-shell structural concept is developed which ensure a huge reduction of single parts and process steps. The main objective of the B-model is to reduce manufacturing costs by 30% and reduce weight by about 5%.

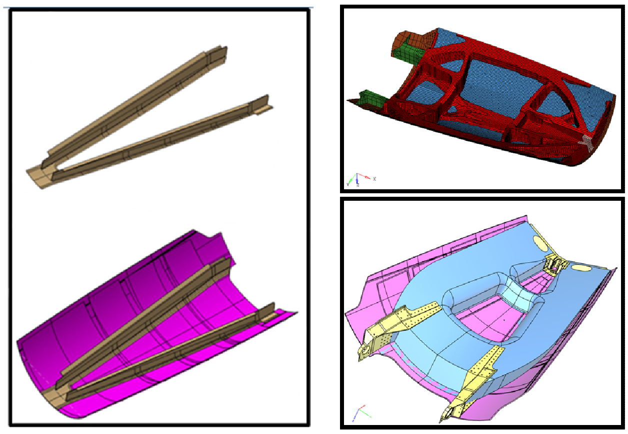

Figure 6. "A"-model (left) and "B"-model (right) derivatives based on EFA T/S airbrake

3. WP2000 – Functional structures

Unmanned air vehicles (UAV) require the transmission of large data volumes via multiband / wideband satellite communication (SatCom). The SatCom radome, Figure 7, protects the antenna against a harsh environment and is a high performance component that has to fulfill requirements from several disciplines. The purpose of the work package WP2000 is to develop and assess technologies to design, manufacture and qualify radomes fulfilling the requirements.

Figure 7. Potential UAV MALE configuration with SATCOM radome

To identify the requirements and their prioritization was a first task. Figure 8 illustrates the main requirements. A major aspect in this context is the electromagnetic transmissivity which has to assure the basic functionality of the radome. In principle there are three different candidates for a radome design, i.e. a monolithic, an A-Sandwich, a C-Sandwich and a Multilayer Thin Layer (MTL) radome, as shown in Figure 9.

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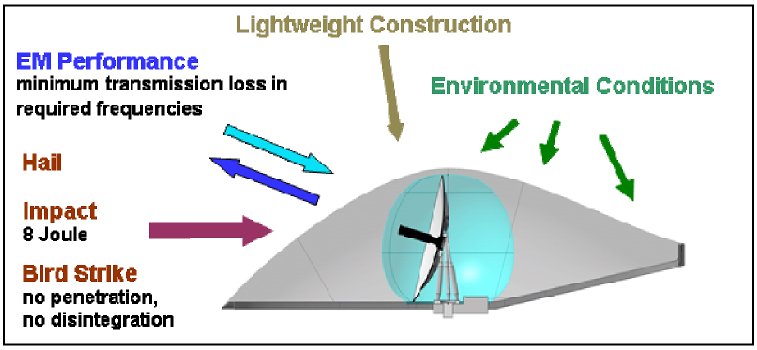

Figure 8. Major requirements for a SATCOM radome

In a next step a suitable electromagnetic solution has been defined and a design developed that considers manufacturability, ensures structural integrity and all relevant criteria for certification. A thin wall A-Sandwich configuration has been defined and evaluated in terms of transmissivity, manufacturing, damage tolerance, and lightning protection.

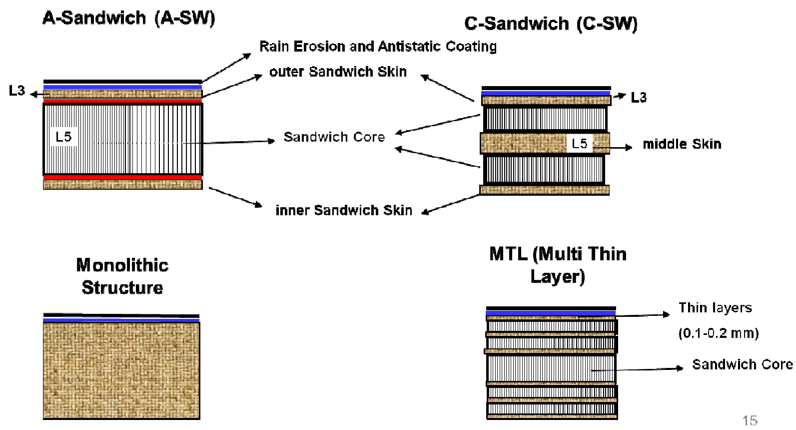

Figure 9. Basic radome design configurations

A building block approach with increasing complexity has been defined and experimental tests conducted on different material and structural component levels and with demonstrators to cover issues of the involved departments achieve a stepwise evaluation and evolution of the technical maturity of the envisaged radome concept.

Promising results have been achieved within the collaboration framework of research institutes and industry and the work will continue to answer more specific questions to increase the technological readiness level (TRL). A more detailed overview of these activities is given in [1].

4. WP3000 - Structural Concepts

The main goal of WP3000 is to address new technologies for new generation manned or unmanned blended wing A/C configurations. Two aspects have been studied here: Internal bays to open in-flight at high Mach numbers as well as the aspect of reduced radar cross section (RCS), also called Low Observability (LO).

The main goal of the R&T activities is to develop advanced capabilities to specify, design and manufacture internal bays. One of the design drivers for such internal cavities is the so called acoustic fatigue issue. Due to instationary aerodynamic effects high static and oscillatory pressure occur in the open cavity which may cause significant damage to the cavity walls as well as to internal system and structural parts. The principle of acoustic load generation and oscillatory pressure is sketched in Figure 10.

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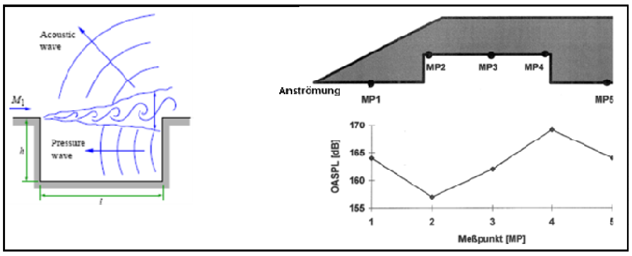

Figure 10. Principle of generation of acoustic loads and acoustic fatigue

For this purpose a numerical tool chain has been developed in order to estimate the acoustic loads as well the impact on the structure and to assess fatigue of the structure due to high-cycle vibrations. The tool chain starts with the aerodynamic analysis (CFD DES) of the instationary flows in the cavity. These simulations have to be performed on the complete A/C level. Figure 11 gives an impression of the pressure coefficient (cp) and pressure distribution for a certain timestep and for a certain flight condition. Based on these results the CFD data have to be processed in order to extract the relevant data to be applied in the last step of the tool chain in a MSC.Nastran-based frequency response analysis of the structure. Based on the computed local stresses and strains, on their levels and number of cycles an estimation of the fatigue life can be performed.

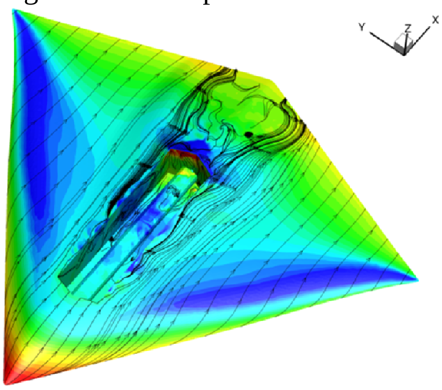

Figure 11. Exemplary CFD DES analysis (here c_p distribution on a blended wing body configuration at a selected time step)

5. WP4000 - Upstream, Ultralight and Affordable Technologies

The objective of the WP4000 is to evaluate and assess new and upstream composite material concepts and solutions with improved performance and reduced costs. Especially for ultralight aircraft platforms such as Solar HALE (High Altitude Long Endurance) with maximum takeoff weights between 50 and 100 kg high performance, thin carbon fiber reinforced composite materials are required. Potential material candidates are so called thin-ply composites with single plies in the order of magnitude of up to 5 time thinner than standard materials such as NCF (non crimp fiber materials or also prepreg). Figure 12 illustrates potential performance improvements with respect to strength (mean values) as well as so called strength “B-values” which consider statistical distribution of strength performance and are used as allowables values during dimensioning and certification of A/C structures.

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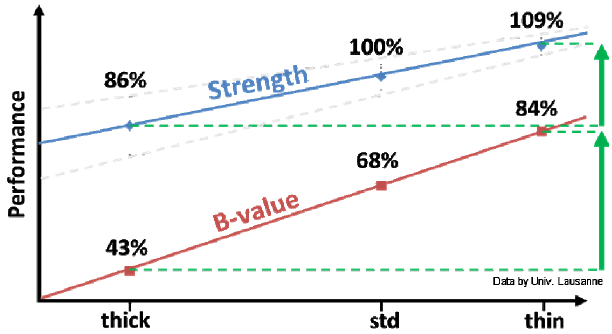

Figure 12. Performance of thick, standard and thin ply composites

A tow spreading machine available at our project partner Airbus Group Innovations (AGI) in Ottobrunn (Figure 13) has been used to spread commercial carbon heavy tows of IMS65 in thinner dry fiber non crimp fibers. Composites plates using epoxy resin have been manufactured by infusion technologies and a coupon test program has been performed.

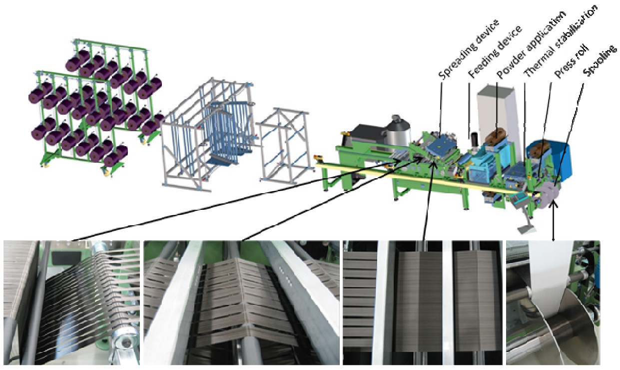

Figure 13. Tow spreading machine at Airbus Group Innovations Ottobrunn

Another example of new material concepts and manufacturing technologies consists in 3D printing or ALM (Additive Layer Manufacturing). This work package has been included into the R&T program FFS beginning of 2016.

6. Summary and Outlook

Within this paper an overview has been given on the four main sub-projects or work packages of the R&T program FFS “Advanced aerostructures”. Four main topics in four main work packages are covered - Structural Bonding incl. demonstration on Eurofighter Airbrake - Advanced multiband radomes for future UAVs - Stealth Design of internal bays - Thin Plies Materials and 3D printing with polymers for spare parts. All considered aspects play a significant role for existing military A/C platforms in terms of upgrades and in-service as well as for new future A/C platforms such as UAV MALE (Medium Altitude Long Endurance).

References

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