CERFAC

42-Month Publishable Report

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Publishable summary

1. Project scope

The CERFAC project addresses many challenges faced in the growing use of composite structures and mainly the transfer of loads between composite parts through innovative designs for joining and assembly.

Today a rapid growth in composite applications for fuselage, wing and other structures (A380 28% and Boeing 787 50% content) has been realised due to their superior 'specific' mechanical properties allowing weight and associated fuel consumption and pollution reductions. However, the substitution of metals with composites has presented formidable challenges to realize lighter, stiffer and stronger, damage tolerant structures that are cost-efficient, regarding development, manufacturing, inspection, or even operating costs.

A major design problem of composite is efficient joining systems for high performance aero-structures. Due to the large number of such interfaces in aircrafts, a solution to these problems is highly promising in terms of weight and cost reductions. It can be stated that current design practices give non-optimal jointing systems that are poor in terms of weight penalties and cost efficiency. Consequently, composite designs are often rejected in favour of traditional metallic concepts.

2. Project objectives

CERFAC's first objective is to provide a catalogue of reinforcement solutions at the locus of fastener holes (rivet holes, bolt holes) or edges leading to lighter, stronger and more damage tolerant designs.

CERFAC's second objective is to introduce innovative and efficient joining concepts combining some of the investigated reinforcement solutions, supporting representative target applications. This contribution would then help reducing further the number of fasteners, while increasing the load bearing capacity and damage tolerance of the assembly

The efforts in the project are directed to allow and favor future (mid-term) introduction and exploitation of the proposed concepts by

- Always considering other constraints such as accessibility, disassembly, repair-ability, inspect-ability, …
- Positioning the approach in–line with current design methodologies and tools
- Accounting for current design, analysis, testing, certification rules and practice.

As the strength to cost ratio is used to classify the performance of the investigated reinforcement solutions and joining concepts, one of CERFAC's main tasks is to identify cost drivers, to predict and to verify cost for each of the latter.

2.1. Targeted applications

The first range of target applications addresses distributed loads and shows a gradation in terms of complexity, from the optimized standard strap or splice to the advanced multi-functional profile.

As a first example of target application to be considered in CERFAC, we can mention generic straps for assembling thin walled structures (see Figure 1).

These straps (so called Butt Straps or Butt Joints) are used in many places, and therefore could be a source of overall weight loss and cost savings, accentuated by the fact that damage tolerance and load bearing capacity could be improved.

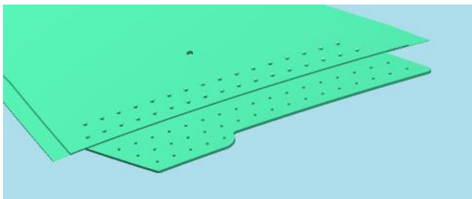


Figure 1. Example of a Butt strap connection

As a second example of target application to be considered in the CERFAC project, we can mention fuselage shells' or barrels' final assembly (see Figure 2). During assembly, splices are generally used (adding significant weight), as well as a large amount of rivets (that increase the costs)

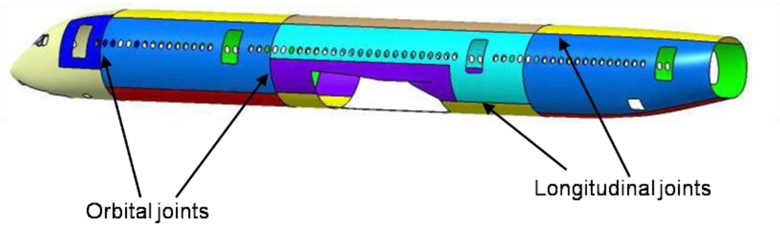


Figure 2. Illustration of longitudinal and orbital joints in final fuselage shells assembly

The third range of applications considered in CERFAC is related to the transfer of concentrated loads, through thicker laminates or thickened zones of thin walled parts, introducing a limited number of fasteners, with different configurations from local patterns of rivets (eg attachment of floor beams to frames) to connecting lugs with a single bolt (eg VTP attachment in Figure 3).

Figure 3. Example of a connection for a concentrated

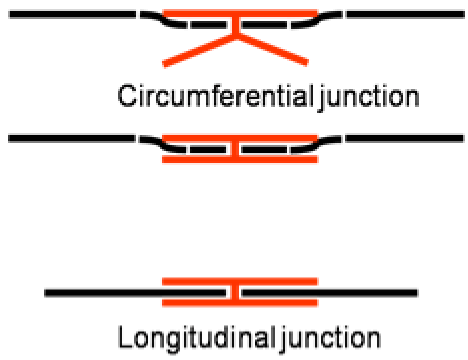
2.2. Innovative reinforcement solutions

Fundamental understanding of the optimal fiber orientation and placement is lacking. Standard optimization tools and commonly accepted optimization approach will be followed (i.e. innovation or TRL increase does not lie in the development of a new optimization methodology). Innovation comes from the thorough understanding of optimal orientations and stacking sequence in fastener areas, with regards to the current design practice (isotropy and local thickening). In terms of new reinforcement techniques using specific manufacturing techniques the paths explored during the CERFAC project are the following ones:

- TFP: tailored fiber placement has already been used for years and has demonstrated smooth integration in the manufacturing chain. The scientific challenge lies more in the optimal placement of tows.
- FPP: For what concerns Fibre Patch Preforms - Figure 4, the objective of CERFAC is to improve the technique already developed by EADS-IWG, and go one step closer to the target application.

Figure 4. FPP carbon fibre reinforcement rosette (EADS-IWG)

- CMP: Compression moulded patches of polymer reinforced with chopped fibres or prepreg are promising for producing stiff, strong and tough parts at low cost, as well as reinforcing add-ons. The idea of CERFAC is to explore new systems that could be compression moulded.
- HYB: Starting from the reference solution using standard laminates (stacking sequence, local thickening) and recommended joining rules, another conceptual innovation comes from the introduction of metallic foils in the lay-up. The novel idea is to introduce metallic foils in fastened areas of thin-walled structures, which would certainly result in a significantly improved strength and damage tolerance while also focusing on cost efficiency.
- GEO: Bonded / geometrically interlocked joints concepts start at a very low TRL. Thanks to this concept, the stress carried out by the rivets is reduced, some of the load being carried by the interlock, with and homogeneous stress distribution essentially ensured by the adhesive bond. The number of rivets should be lowered, the damage tolerance should be improved
- BSB: new concepts, including H-profiles, which might be assembled using preforming then B-stage bonding. Additional fasteners might or might not be necessary.
- PRO: The last step of conceptual innovation in CERFAC is the introduction of multi-functional profiles combining the stiffening and joining roles.



Reinforcement solutions are developed for one or several applications. In each case the new solution will be compared to a “reference” type that is taken from the current state of the art (standard laminate solutions with local thickening from current design rules or metal hybrid solutions). Also, the possibility to include other emerging solutions is left open.

3. Results Achieved at the end of the second reporting period

The third reporting period covered a 12 month lapse during which the different partners in the CERFAC project dedicated research efforts to the development of the different reinforcement methods on small to medium-sized specimens, and working extensively on preforming, manufacturing, machining and finally testing of different configurations. Also, in parallel the design for the different applications on which these reinforcements are going to be tested is updated in order to further compare a reference and an improved design.

With 12 months to go in the project, the design of the reinforcement concepts are well defined and processes have been put into place in order to achieve the desired results.

In Work Package 2 – Design and numerical simulation activities allowed to predict the behaviour of certain reinforcement to either improve and make corrections to the design or then to perform sensitivity analysis and optimization on the geometry of reinforcements. Advanced simulation developments also allow a better representation of the damage and failure of assemblies of complex geometries. Validation of simulation results are done for the moment mostly on reference and small coupon scale.

A large amount of manufacturing effort has been put into the last period by different partners in the project to setup the manufacturing processes (for example 3D woven profiles or surface treatment of titanium inserts) to produce the reinforcement test specimens planned in the manufacturing matrix. The main current outputs from this work package are:

- Butt strap application reference and reinforcement specimens for single lap shear
    - Flushed patches
    - Tailored fibre placement
    - Ceramic particle reinforcement
- Manufacturing of titanium foil insert replacement specimens
- Concentrated loads lug joints
- Thin ply patches manufacturing
- 3D woven profiles for PI-joints
- 3D woven profiles for H-joints and B-stage bonding
- Manufacturing of several reference specimens that will also be tested
- …

Most of the initial reinforcement solutions are still under investigation and development. Results from testing has been performed on various test specimens on E-level (characterization of individual constituent and material properties on fibers and resins or adhesives), D-level tests on simple assembly coupons (single lap shear tests, tension tests, open hole compression,…) and C-level tests too (multiple fixation points, larger specimens and more complex load cases).

Work package 4 is dedicated to the testing of all the reinforcement solutions for different typical applications. The final revision of the tests matrix that took place during the third reporting period allowed to modify and refine the requirements from the different partners in terms of testing and plan them out over the coming remaining months of the project. Tests have been carried out at several universities, research centres and at VZLU with material circulating between partners.

Finally, Work package 5 has started but results are currently limited to the final catalogue of reinforcements. This allows to identify what are the promising solutions that were kept and studied over the project as well as the qualitative overview of the potential benefits that we can expect from these. The performance and cost analysis of the reinforcement solutions has begun but has not currently led to a detailed analysis for most of the reinforcements. The majority of the work for this last work package is planned for the next reporting period..

Some significant delay was observed during this reporting period due to the initial delay of several months at the end of the first reporting period and the shift in use of effort and refocusing of activities concerning some of the partners. An extension of duration of the project has been approved and the new official end date of the project will be December 2014.

4. Major outputs of the project

There are several major outputs planned throughout the project. The first that gathers all the results from the project is the catalogue of reinforcement solutions at the locus of fastener holes (rivet holes, bolt holes) or edges leading to lighter, stronger and more damage tolerant designs. Predictive analysis methods and optimisation techniques supported by extensive testing will enable cost and weight efficient solutions.

Secondly, the project focuses on several specific reinforcements and these will be developed throughout the project in order to achieve a higher level of maturity and hopefully allow using them in an industrial environment. The table below summarized the outputs expected for different reinforcement solutions. Concepts focus on design of the reinforcement solutions, testing and characterisation while process development will dig deeper in the fabrication of these reinforcement solutinos with respect to the requirements of industrialization and integration in the manufacturing chain.

Description	Innovation type
Basic optimization of standard stacking sequences in order to improve strength. Combination of fastener area reinforcement solutions for conventional joints. Reducing the number of fasteners by reducing the stress carried by these. Reducing the assembly cost.	Concepts
Compression molded patches added on fastener holes: process set-up and patch optimization. Towards automated / cost effective process and patch, towards a reduced stress concentration.	Concepts and Process
Exploration, characterization and optimization of complete dry assembly process. Towards fastener free structures. Injection and assembly are simutaneous, thereby reducing the assembly cost.	Concepts and Process
Exploration, characterization and optimization of preforming + B-stage bonding for longitudinal joints: mechanical and chemical issues.	Concepts and Process
Design, analysis and validation of multi-functional profiles combining the stiffening and joining roles. Reducing the number of rivets by eliminating splices and reducing the stress carried by these. Reducing the assembly cost.	Concepts
Transfer of hybrid laminates technology around fastener holes to thinner structures.	Concepts
Exploration of low cost alternatives (other metallic foils than Titanium) for hybrid laminates. Underlying design, analysis, modeling, simulation and optimization activities. Reducing the cost of hybrid laminates for improving joint resistance.	Concepts
Innovative design of connecting lugs: combination of different reinforcement solutions. Minimization of the number of fasteners and of the assembly cost.	Concepts

5. Project internet site

The description of the project, the consortium involved and further details can be found at the following webpage:

http://www.cerfac-project.eu