PROJECT

CELPACT

Cellular Structures for Impact Performance

Funding: European (6th RTD Framework Programme)
Duration: Sep 2006 - Sep 2009
Status: Complete with results
Total project cost: €3,140,446
EU contribution: €2,430,000

Call for proposal: FP6-2005-AERO-1
CORDIS RCN: 79967

Background & policy context:
The use of composite materials and new metal alloys in aircraft structural components has grown steadily with each generation of aircraft. The development of a complete pressurised fuselage in composites or hybrid metal/composites represents a big challenge, particularly because of increased vulnerability of these materials to impact threats.

The big jump in technology needed for the realisation of a new fuselage for the next-generation Airbus requires new production technologies and materials for integrated structural concepts. Current concepts for fuselage structures introduce composites in the fuselage barrel with conventional frame/stringer concept monolithic skins. In the longer term the aircraft industry sees a potential for twin-walled sandwich structures due to their much higher shell-bending stiffness than single skin designs and far higher strength/weight ratios.

They would allow novel highly efficient fuselage concepts without stringers and with much larger frame spacing, and would also be appropriate for next-generation aircraft concepts such as the blended wing. Current aircraft sandwich structures are particularly vulnerable to impact damage, due to their thin composite skins and low-strength honeycomb or polymer foam cores. Thus for efficient lightweight future aircraft structures there is a requirement to develop new sandwich materials concepts with improved impact resistance.

CELPACT is an upstream research project concerned with the development of breakthrough technologies and design tools for future airframe structures with high efficiency and safety. It has been prioritised by the European Aeronautical Scientific Network EASN. The consortium from five European countries contains seven leading universities with research institutes and aircraft industry partners.

Objectives:
The main objective of the project was the development and design of cellular materials and twin skinned sandwich structures made from hybrid composites and metals.

CELPACT led to progressive fabrication technology for cellular metals, based on selective laser melting and the development of new fabrication concepts for hybrid composite sandwich structures with folded cellular composite cores.

Computational methods were developed based on micromechanic cell models with multiscale modelling techniques for understanding progressive damage and collapse mechanisms and used for structural analysis.

Impact performance was critical for sandwich aircraft structures and simulation tools were used to design efficient impact resistant aircraft structures. Structural integrity of these advanced cellular structures have been assessed by testing generic cellular beam and shell structures under high velocity impact conditions relevant to aircraft structures.

The objectives of CELPACT were:
A. The development of new classes of materials for aeronautical structures based on:
   - Cellular metallic core structures;
   - Cellular hybrid composite core structures.

B. The development of new manufacturing processes based on:
   - Laser forming for manufacturing complex three dimensional periodic lattice structures;
   - Thin sheets brazed for making periodic closed cell metallic structures;
   - Folded composite cell structures from paper and prepreg;
   - Fabrication of twin-walled sandwich structures with the innovative cores.

C. The development of numerical tools to:
   - Predict the mechanical behaviour of the cellular materials;
   - Optimise the cellular and sandwich concepts with regard to applications;
   - Develop design tools for predicting impact damage and failure in sandwich structures.

D. Technology validation studies to demonstrate viability of these new materials for future aircraft structures:
   - Validated design procedures for novel cellular and sandwich structures;
   - Validated impact design tools;
   - Road map for dissemination to aircraft industry design teams.

Methodology:

The CELPACT project focused on basic research, for implementation by industry in an 8 to 12 year time scale. The research included next generation manufacturing techniques for both composite hybrid and metal cellular materials and structures. A wide range of candidate materials and geometries were considered: cellular hybrid composites (CHC) with folded composite core structures, cellular metal (CM) with closed cell cores and selected laser melted lattice cores.

The project was structured into five work packages (WPs) as follows:

WP 1: Manufacture of cellular structures

The main aim of this work package was to define the cellular materials and to manufacture CM and CHC materials. In the first phase of the project, a three-ply carbon composite laminate with unidirectional plies and a stacking sequence of [0 degrees / 90 degrees / 0 degrees] was used for the cell wall material. Based on the knowledge gained from these first specimens, some enhancements were implemented in the second phase foldcore structures. First of all, woven fabric prepreg material was used for the cell walls, as it is easier to handle during manufacturing compared to the unidirectional material. The unit cell geometry was optimised in a numerical study in order to obtain increased compressive properties while maintaining the same global density of around 110 kg/m3. Furthermore, a dual-core configuration was investigated, using two separate foldcore layers - one carbon foldcore and one aramid foldcore - and an aramid plate in-between. This concept may allow for a two-phase energy absorption behaviour. All sandwich structures consisted of quasi-isotropic carbon / epoxy skins, which were bonded onto the foldcores with an epoxy-based pasty adhesive. The increased performance of these second phase structures could be verified during the compression and impact test series, demonstrating that the foldcore structures offer the designer certain measures to tailor the core's properties for specific requirements (like the compressive behaviour). These measures are primarily the choice of cell wall material, cell geometry and single core / multi-core configuration. However, it has to be stated that the discontinuous manufacturing process, which was used for the production of these carbon foldcores, is more or less limited to the prototype level, because the final foldcore plate size is of limited dimensions, which is insufficient when it comes to the manufacturing of large quantities on an industrial level.

**Parent Programmes:**

FP6-AEROSPACE - Aeronautics and Space - Priority Thematic Area 4 (PTA4)

**Institute type:** Public institution

**Institute name:** European Commission

**Funding type:** Public (EU)

**Lead Organisation:**

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**Partner Organisations:**

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| **The University Of Liverpool** | Senate House, Abercromby Square  
LIVERPOOL  
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| **The Chancellor Masters And Scholars Of The University Of Oxford** | University Offices, Wellington Square  
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Key Results:

During CELPACT basic research was carried out on novel sandwich materials for future aircraft fuselage and wing structures with higher performance and lower fabrication costs than current stringer stiffened aluminium panels. Advanced manufacturing techniques were developed for sandwich structures with cellular cores from hybrid composites and metals giving high strength/weight and improved impact resistance under critical aircraft load cases. The composite sandwich structures had carbon composite skins and folded cellular composite cores of resin impregnated aramid or carbon paper, with trapeze-form zig-zag folding patterns, which gave an open repeating cellular structure.

Cellular metal cores used selective laser melting (SLM) with stainless steel and titanium as core materials. With the rapid prototyping SLM technique open cellular lattice structures at the micro scale were developed with precise microstructure geometry, for use in sandwich structures with carbon/epoxy or aluminium skins. Computational methods were developed based on micromechanics cell models with multiscale modelling techniques for understanding progressive damage and collapse mechanisms and used for structural analysis. The simulation tools were used to design and optimise efficient impact resistant aircraft sandwich structures. Structural integrity of the cellular structures was assessed by high velocity impact tests on generic cellular beam and shell structures relevant to aircraft panels.

Technical Implications

Project contribution to Carbon reduction:

New sandwich materials with structural composite and cellular metallic cores permit aircraft primary structures with a lower weight to be developed for fuselage and wing panels which meet safety requirements under critical impact loads. These structural weight reductions reduce fuel consumption and carbon emissions over the 30 year life of aircraft.
Innovation:
CELPACT developed a continuous manufacturing process for a family of folded composite core structures and a selective laser melting technology for the production of metallic open microcellular lattice structures. Computational methods were applied to select and optimise cell microstructure and design lightweight impact resistant sandwich structures with these novel cores.

Project transferability:
CELPACT developed new manufacturing technologies and improved design tools for advanced sandwich materials with structural composite and metallic cores. This technology for advanced materials will find applications in other industries, automotive, rail and marine where lightweight structures are the key to future energy and fuel cost savings.

Policy implications
The European aeronautics industry meets an important societal need for improved mobility through lower travel costs, better service, higher safety and environmental standards. CELPACT contributes to this strategy with basic research on next generation aircraft structures which will lead to more affordable, safer, cleaner and quieter air transport.

The European aeronautics industry and its supply chain has over 1 000 000 employees. To maintain or increase world market share from the current 50% requires innovation. New materials and design technologies developed in CELPACT can lead to more efficient aircraft structures, improving competitiveness and ensuring future employment in the industry.

Documents:
- Project Presentation (Project presentation)

STRIA Roadmaps:
Vehicle design and manufacturing

Transport mode:
Air transport

Transport sectors:
Passenger transport, Freight transport

Transport policies:
Safety/Security

Geo-spatial type:
Network corridors