# The "C-triplex" approach to design of CFRP transport-category airplane structures

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**ABSTRACT**

The quality of CFRP composites is highly dependent on the manufacturing process. Laminate performance is greatly affected by the void and resin fractions. Thicker structures result in lower quality. Thin composite laminates manufactured at high pressures offer best quality. However, impact and damage tolerance, buckling, and concentrated stresses for rivets and bolts require redundancy which increases the thickness. Thick laminate structures lower CFRP mechanical properties. Composite laminates have advantage of good surface smoothness and low tolerances. A thin laminate tailored for the specific application with good monitoring system and support for buckling prevention with impact protection offers good solution. The bearing laminate is encapsulated between two supporting layers with excellent outside tolerances and smoothness representing the C-triplex concept. Inserts are included in the constructions for bolts or rivets. On the bearing laminate a monitoring tissue is installed for load history and structural integrity. The three layers are arranged in a way to house foam that provides support for buckling and thermal insulation. The C-triplex macro panels are bolted to a titanium or aluminum alloy skeleton of the aircraft body. C-triplex panels contain all ducts for the wires, pipes, and plugs necessary for the body interior.

**Keywords**: Composite material, C-triplex, CFRP, Aircraft structures, Modular construction.

## 1. INTRODUCTION

Building structures have been constructed in one plant, transported and reassembled at construction site since 1837. The world's first prefabricated, pre-cast paneled apartment blocks were pioneered in Liverpool (J.A. Brodie, 1906). The last of prefabrication seems to be David Fisher's dynamic towers with entire floors that rotate independently around a concrete core, skyscrapers which follow the sun, or simply respond to the whims of their residents for a different view.
Dynamic towers will be one of the world's first prefabricated skyscrapers with 40 factory-built modules for each floor. Almost 90% of the high-rise will be built in factory and shipped to the construction site. Predicted construction time of the entire building is 22 months or 30% shorter than for a normal skyscraper of the similar size. Prefabrication will decrease the number of construction workers from 2000 to 700. More traditional prefabricated buildings are manufactured by fabricating a steel or concrete skeleton on site and then assembling the prefabricated panels onto it. The normal construction rate is one floor per day (see Fig. 1).

**Figure 1:** The prefabricated panel assembly.

A similar concept of prefabricated panels can be utilized in construction of aircraft fuselages. A metal skeleton of the aircraft fuselage is assembled and then the prefabricated triplex panels are bolted on this structure as shown in Fig. 2. Special care should be taken to avoid that screws/bolts directly affect the resin or the CFRP. The inserts are designed to withstand axial loads on screws [12].

**Advantages of thin laminates designed by autoclave and vacuum bag molding**

The best carbon fiber composites used on primary class-one structures are fabricated by placing layer upon layer of UD pre-impregnated (prepreg) material to the prescribed ply profile and fiber orientation. Numerical control ATL machines are currently limited in production applications to flat lay-up and significant effort is being directed by machine manufacturers at overcoming these problems associated with laying on the contoured surfaces of the mold.

**Figure 2:** A single Triplex panel (right) is bolted to the skeleton (center) to form a part of the fuselage (left).

A carbon-epoxy mold is manufactured and accurately polished. The laid-up component with its mold are then enclosed in a flexible bag and closed in an autoclave. A pressure vessel containing gas at pressures, generally, up to 1.5 MPa (15 bar or 220 psi) and temperatures required to cure the matrix is employed. The flexible bag is first evacuated before pressurization. This process is designed to reduce porosity down to 1% as shown in Fig. 3, and to minimize matrix content down to 40% volume fraction (see Fig. 4). Large autoclaves are capable of housing complete wing or tail sections of FAR/CS part 25 airplanes [2-3].

The idea behind the "C-triplex" panel is an innovative technology conceived to overcome some existing problems regarding design, manufacturing, and maintaining of aircraft airframes. In fact, modern aircraft, in addition to being complex and costly to manufacture also require frequent workload intensive and expensive maintenance, which is certification and safety critical. For example, some of the required maintenance for commercial airplanes operating under Title 14 Code of CFR (shortly FARs in USA) parts 121 and 135 are the scheduled detailed A, B, C, or D checks [7]. B-checks can be incorporated into successive A-checks. For example, a scheduled comprehensive heavy maintenance visit (HMV) or D-check to be conducted approximately every 5 years or 25,000 flight hours whichever comes first can take up between 35,000 and 40,000 man-hours of work and have aircraft out-of-service for 2 months requiring large and expensive hangar spaces. Practically, the entire aircraft is disassembled and especially checked for corrosion and health of structural elements. The cost of such maintenance can run into several million US$ and must be planned in advance. Typically, a transport category aircraft will undergo 2-3 D-checks before being retired. A D-check will include all items in A and C checks. For example, design service objectives (DSO) for wide-body large transport-category Boeing B777 are 40,000 flight cycles, 60,000 flight hours or 20 years. DSO's establish design goal by airplane manufacturers which represent expected product life duration before the aircraft is retired. A narrow-body Boeing MD-80 (formerly McDonnell-Douglas) has DSO of 50,000 flight cycles, 50,000 flight hours, and 20 years of expected service life. Short- and medium-range commercial airplanes have larger number of takeoffs, landings and pressurization cycles compared to long-range wide-body large aircraft, such as B747/767/777, A330/340/380, which spend most of the flight time in cruise. Operating an aircraft beyond DSO will cause prohibitively costly maintenance and the aerospace technology is advancing so rapidly that after 20 years in service practically any modern commercial aircraft today will become obsolete [13].

The "C-triplex" concept is the result of a design idea conceived to overcome some avoidable, as well as known problems associated with composite fuselage panels, namely:

- Poor impact resistance.
- Poor surface finish on the face opposite to the mold with related additional work of finishing.
- Difficulty in detecting cracks and other damages
- Problem with joints

Moreover, the "C-triplex" concept, based on the structural design of large prefabricated panels, allow us to:

- Streamline, simplify, and reduce costs in the manufacturing process of airplane fuselages.
- Minimize the operational costs of the aircraft and in particular those arising from the time-scheduled maintenance.

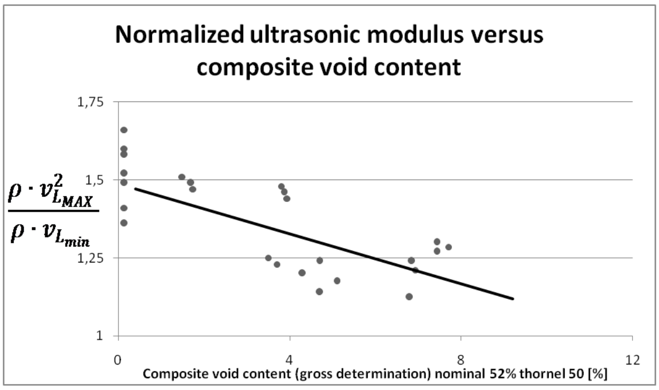


**Figure 3**: Normalized elastic modulus vs. void content. A void content up to 2% is normal [1].

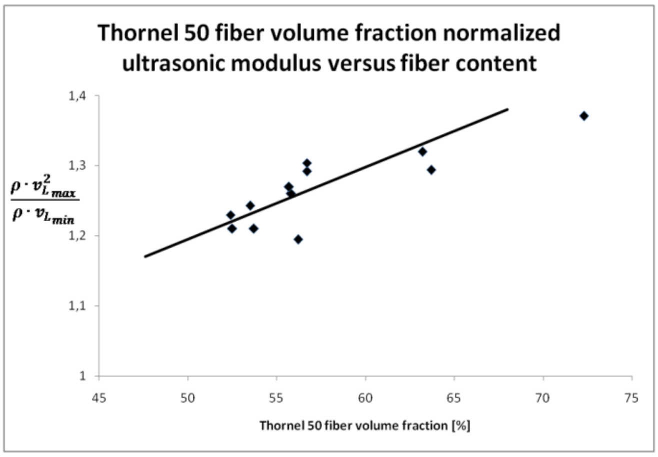


**Figure 4:** Fiber content versus elastic modulus. A volumetric fiber content of 56% is typical for a good-quality part [1].

**The general Structure [11]**

The C-triplex is named due to its particular structure involving three sandwiched layers. The middle structural composite panel (2) acts as a primary load carrier and is encapsulated in a protective shell formed by layers (1) and (3). Such construction design enables one to overcome the primary disadvantage typical of composite materials, i.e., relating to the poor impact resistance. In fact, in this way, the outer faces of the shell fulfill the function of a shock absorber, while the central core, totally encapsulated and protected, retains its function as a primary load carrier. Also some parallel load sharing and limited fail-safe design philosophy is achieved in this way enabling somewhat smaller core structure than if were solely responsible for the total load. The fabricated C-triplex panel represents a single finished structure to be transported and mounted to the fuselage skeleton of the aircraft. Thus, the design solution utilizing C-triplex panels in aerospace/aircraft industry is conceptually very similar to prefabricated sub-structures used in construction of buildings.

**The 3D frame**

As an example, we first examine a cylindrical airframe structure with diameter of 8.3 m which is, in principle, the fuselage part (plug or insert) of a transport-category airline-type airplane and is shown in Fig. 5. The fundamental need to reduce the operating weight of aerospace structures is therefore addressed by this simple structure involving C-triplex panels with smaller number of stringers and ribs. This solution has been possible due to the structural design of the C-triplex, which becomes the primary load carrier. The choice of the primary material of the fuselage rests on titanium alloys, due to its excellent mechanical properties, resistance to high temperature, corrosion resistance, as well as high performance-to-weight ratio.

**The construction philosophy**

The production cost of composite structures is still the biggest obstacle to their widespread adoption in aerospace/aircraft structures. This is mainly due to the design and production approach that still treats the composite material as "black aluminum", with a structure made up of many separate parts connected by countless rivets. In this regard, the C-triplex design philosophy is aimed to a structure of larger size, mainly to reduce weight and assembly time. The optimized version of a single C-triplex panel is 140 mm thick, has an internal area of 5.2 m2 with a width of 2200 mm.

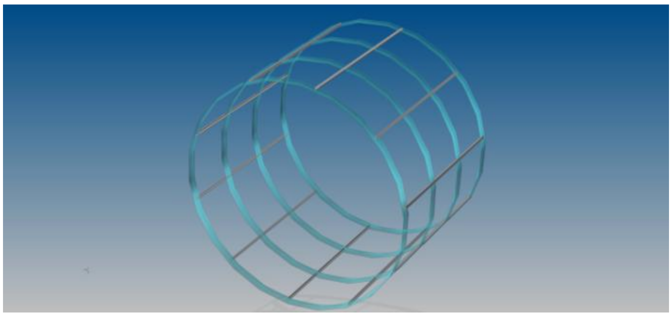

**Figure 5**: Fuselage assembling frame.

**The manufacturing process**

An example of C-triplex assembly is depicted in Fig. 6. Both protective shells (1 and 3) and the core (2) are made of CFRP in the following processes:

- Autoclave vacuum-bag molding (AVBM) for the core.
- Resin transfer mold (LVARTM) for the outer shells.

These manufacturing methods originated from the need to obtain a material, more or less, resistant to the detriment of other factors, such as, surface finish or production speed.

**AVBM and LVARTM and the selection reasons**

The AVBM enables production of high-performance materials and quite close to theoretically predicted best composites. This is achieved by utilizing high performance fibers, generally in UD prepreg form, and then with high pressure applied to the "vacuum bag". The pressure applied is much greater than the atmospheric pressure and serves to improve the critical compaction between the fibers and resin. This procedure limits the presence of voids and the matrix content between the laminas, thereby decreasing the porosity of the material while improving the mechanical characteristics. Unfortunately, a great disadvantage of this process is the poor surface finish on the side which is not facing the mold or the external face shown here in Fig. 7.

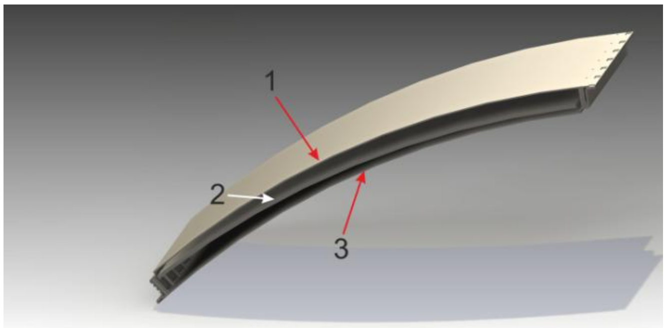


**Figure 6**: Cutaway drawing of the C-triplex panel. Protective shells (1 and 3) enclose the core structure (2).

It is reasonable to conclude that the utilization of AVBM as the advanced method of C-triplex fabrication would be the ideal one if it did not result in such poor surface finish on the external face of the panel. Indeed, this unfortunately limits the use of C-triplex design, as it would require additional machining and surface finishing before assembly onto fuselages. This would result in inevitable increase in production costs.

To overcome the major shortcoming of AVBM and at the same time maintain excellent mechanical properties obtained, a compromise can be reached by encapsulating the central core in a protective shell which is also made of CFRP, but manufactured in a LVARTM process.

The advantage of this technology is the remarkable versatility in product characteristics achieved and in cycle times required. Additionally, parts of complex geometry can be manufactured allowing rapid series production by high precision molding. But, the aspect for which the LVARTM is preferable to AVBM for the fabrication of the shell of the C-triplex panels is the excellent surface finish on both panel faces so that no additional and tedious surface finishing is required. Indeed, the idea of obtaining, at the end of casting, a shell in CFRP perfectly “clean”, without further finishing processes and with limited constraints in geometry, allows us to fabricate a panel "ready to use", internally reinforced by a sturdy lightweight core.

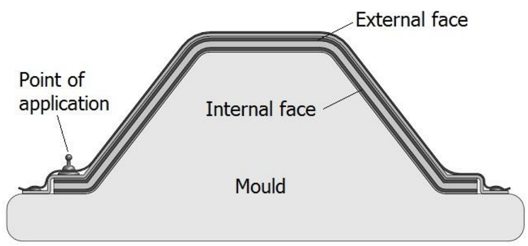


**Figure 7**: AVBM production process.

The LVARTM technology allows the use of inserts of different shapes in order to obtain mating shapes and slots. It also allows the manufacturing of pipes within the panel, passage holes, ducts, and many other possible cavities and protrusions. Accordingly, a C-triplex prefabricated panel designs offer many advantages and can be conveniently assembled and mounted onto a basic skeleton to form the airplane fuselage. Specifically, the panel C-triple arises as the only element of separation between internal space and outside of the aircraft. The inner part may also include the classic components for fittings, such as the one of the seats, and the upper port objects.

After outlining the manufacturing and fabrication techniques and the reasons for their choice, we will now proceed to explain construction details of the C-triplex panel. Specifically those conceived to reduce maintenance costs as well as those relating to the assembly process.

**Optimizing maintenance costs**

Maintenance of airplanes can be scheduled (planned/preventive) and unscheduled. Operators of transport-category airplanes (certified under FAR/CS 25) follow a continuous inspection program. Maintenance represents set of periodic activities/inspections necessary for the re-establishment and continuous maintenance of aircraft airworthiness as defined by national regulatory agencies (e.g., FAA, EASA, Transport Canada, CAA, etc.) and under auspices of ICAO. Such activities include inspections, audits, repairs, replacements, testing, changes and recertification works drawbacks, in application of the maintenance schedule and anything else made mandatory by the regulatory authorities responsible for the certification of aircraft and parts. Any unscheduled maintenance that occurs after unexpected system failure can be very costly as it may also disrupt and create havoc in flight schedules.

The most expensive inspection schedule is, of course, a D-check which includes all the activities of a C-check with the addition of more specific NDT. Indeed it is necessary to use NDT inspection techniques to detect otherwise invisible cracks and/or de-laminations in the common composite panels.

The C-triplex panels due to the use of a monitoring network [4] of stress gauges appropriately glued to the central core structure and wired to a central control system is capable of evaluating and analyzing the stress state of the entire panel in real time. Additionally, the presence of accidental blows or surface cracking can be detected as shown in Fig. 8. In this way C-triplex panels offer integrated condition- and health-monitoring of the essential structural elements. Such solution allows the replacement or relaxation of the scheduled maintenance program to an on-demand maintenance in which the repairs will be carried out only in case of failure and after an unambiguous fault signal from the computerized structure health monitoring system is received. This represents a serious advantage since at least parts of the maintenance programs become on-demand and time and costs are considerably reduced. Accordingly, the C-triplex panels satisfy some requirements of the passive smart materials and structures. The use of health and usage monitoring system (HUMS) offers distinctive advantages [7] and is a small step toward a really actively “smart” structure where physical characteristic of the system can be varied to meet various stress and strain goals for flutter control, noise control (in cockpits and fuselages), etc.

**Insulation system**

Thermal insulation in the C-triplex panel is entrusted to the polyurethane foam. Polyurethane ability to conform perfectly to volumes and surfaces and adhere firmly to any type of support to be insulated makes it the insulation material of choice. An illustration of polyurethane foam to be used for C-triplex panels is shown in Fig. 9.

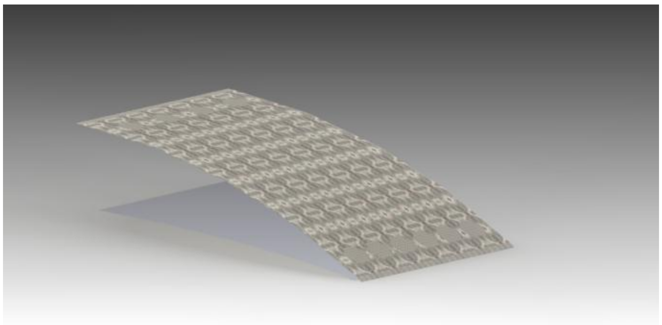

**Figure 8**: Strain and damage monitoring of CFRP in impact loading using a fiber Bragg grating sensor system.

**Polyurethane insulation**

In addition to its known heat insulation properties, the polyurethane guarantees lightness, favorable mechanical characteristics, low-temperature stability, and rigidity to the system in which it is injected. In this regard, the central core of the C-triplex, as well as the monitoring network in glass fiber, is entirely insulated by polyurethane foam. This provides for greater structural rigidity as well.

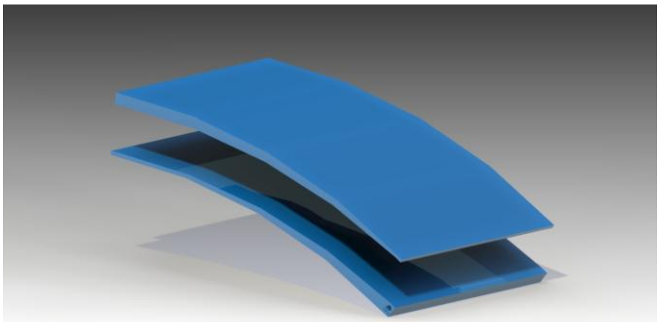

**Figure 9**: Polyurethane insulation.

Furthermore, since the C-triplex is a prefabricated panel, each system will contain passages for electrical wires, ventilation systems, and any other tooling necessary for the operation of the aircraft. The individual components up to a complete representation of the internal structure of a C-triplex panel are shown in Figs. (10-12).

**Alternative connections**

The idea of a composite panel totally interchangeable, in addition to the advantages so far described, significantly reduces the number of connecting organs necessary for its assembly, to the advantage of the reduction of the structural weight of the aircraft.

In the field of aircraft construction, in fact, rivets are the most widespread permanent connection. It is easy to imagine how the number of rivets required to join together parts of an aircraft is very high: for example, the Airbus A380 has a rivet population of about 3,000,000.

In this regard, the function of connection between C-triplex and fuselage is entrusted to the use of few bolts in alternative to that of the rivets. This option optimizes the total cost of a plane, and in particular, those relating to labor for the assembly of the panels.

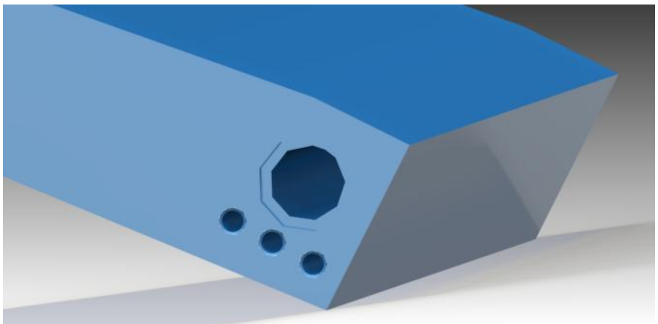

**Figure 10**: Internal ducts for wires, pipes, and services.

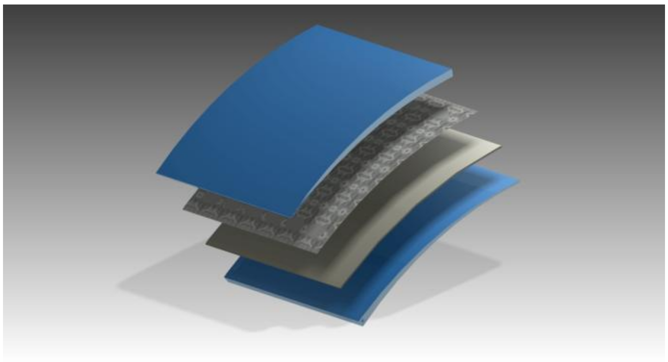

**Figure 11:** Exploded view of the core, network monitoring and polyurethane insulation.

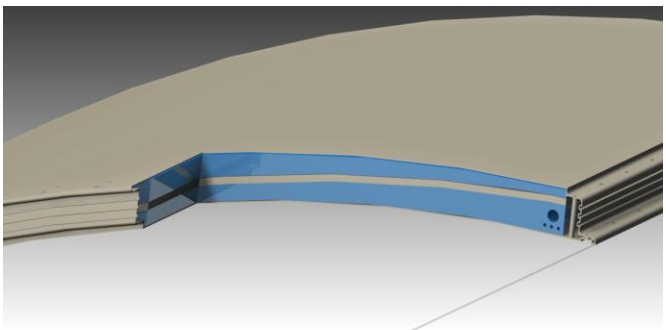

**Figure 12:** Section of finished complete C-triplex panel.

**Advantages of a prefabricated panel**

The following images depicted in Figs. (13-16) illustrate two production processes and assembly of the common composite panels for aircraft line. Specifically, the first technique is used for the Airbus Industries A380. The technique of "Fiber Metal Laminate" involves the use of sheets of aluminum alloy alternated with layers of composite glass fiber GLARE.

**Figure 13**: Surface finishing (1) (Courtesy of Airbus Industries).

**Figure 14**: Surface finishing (2) (Courtesy of Airbus Industries).

**Figure 15**: GLARE layers (1) (Courtesy of Airbus Industries).

**Figure 16**: GLARE layers (2) (Courtesy of Airbus Industries).

It is easy to observe how elaborate and expensive different stages of production and finishing of the existing panels not

based on C-triplex concept are. Another technique often employed in modern composite aircraft manufacturing is the tape winding method as used in a new Boeing aircraft (B787) and is shown here in Figs (17-18). This method is specific for the production of hollow components with cylindrical symmetry, such as pipes, poles, and tanks. It consists of winding fibers impregnated with low viscosity resin on a spool with a rotating spindle. It is again easy to realize how tape winding needs to be processed through several different production steps and how demanding is the maintenance and repair of a single panel in the case of cracks and surface damage.
With the C-triplex manufacturing philosophy many difficulties involving repair and maintenance are eliminated. The stock-holding of spare panels ensures a quick replacement in case of cracks without having to rebuild the coating. In addition, the fastening system to the fuselage, as well as to the adjacent panels, through the commonest bolts further simplifies the assembly. Moreover, any assembly errors can be corrected with an immediate replacement, which are unheard of utilizing existing standard techniques.

**Manufacturing details**

C-triplex manufacturing details are shown in Figs. (19-24). Individual panels must be assembled and disassembled easily from the fuselage while ensuring good sealing and contacts with adjacent panels. For this purpose a system of interlocking male-female connectors on each side of the whole panel is designed providing greater stability to the link.

**Figure 17**: Tape winding (Courtesy of Boeing).

**Figure 18**: Tape winding (Courtesy of Boeing).

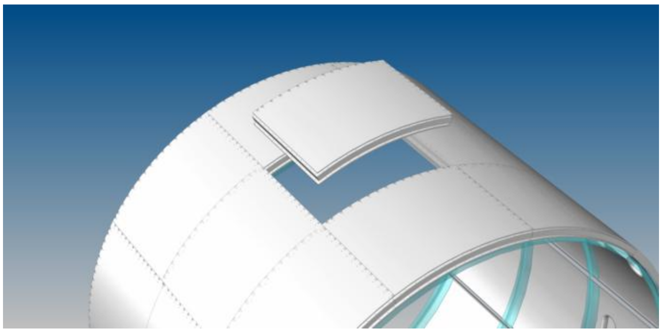

**Figure 19**: C-triplex panel assembly in an airplane fuselage plug.

A system of bolts along each side of the joints rigidly locks the panels to the fuselage. Along the sides of the panel the guides for the insertion of O-rings, i.e., rings of elastomer (rubber) of circular section, are included which ensure perfect sealing in the pneumatic connection. The last and final project provides for a CFRP-LVARTM shell thickness of 3 mm and that of the CFRP-AVBM central core of 2 mm the total mass is around 15 kg/m2 for a typical airline-type airplane body (including titanium-alloy bolts and rubber liners). Bolts are used to simplify the assembling process and the on-site maintenance by panel replacement avoiding time-consuming and process-critical composite repair.

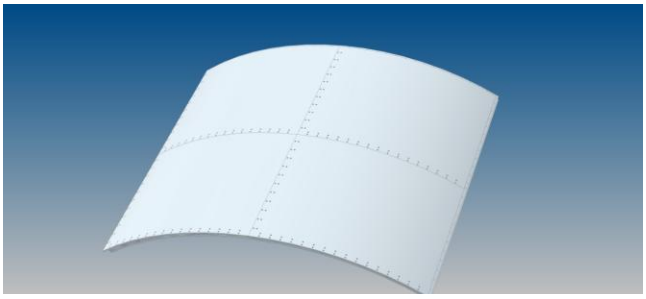

**Figure 20**: Four bordering C-triplex panels forming a cylindrical-shape part of the fuselage.

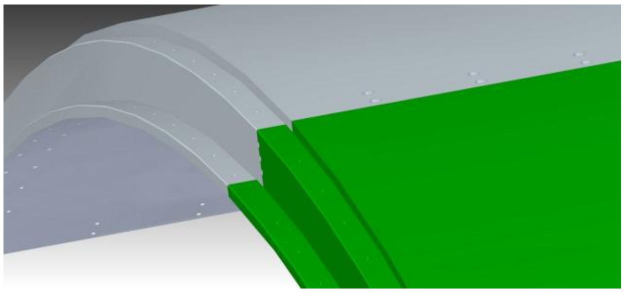

**Figure 21**: Male-female C-triplex panels coupling.

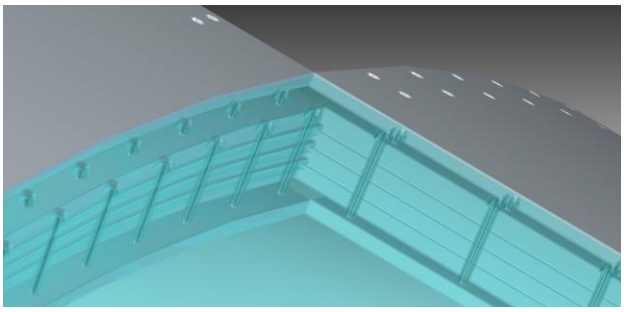

**Figure 22:** Inserts for bolts (1).

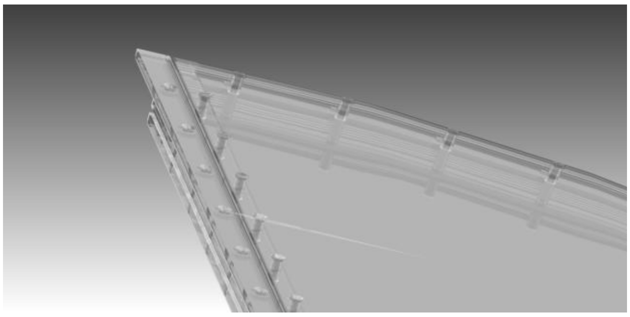

**Figure 23**: Inserts for bolts (2).

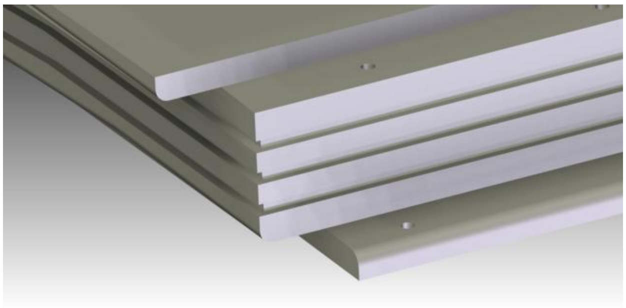

**Figure 24**: O-ring seats.

**Buckling stabilization through the C-triplex approach**

Thin-panel buckling represents a major structural and stability problem for many airplane parts such as wings and fuselages. A theory of buckling of thin plates is complicated and not to be addressed here in any detail. To appreciate the complexity of the buckling of thin uniform-thickness plates let us write a linear partial differential equation, originally derived by Saint Venant, for the thin flat plate deformation with no bending (lateral) forces [6]:

$$\frac{\partial^4 w}{\partial x^4}+2\frac{\partial^4 w}{\partial x^2 \partial y^2}+\frac{\partial^4 w}{\partial y^4}=\frac{1}{D}\left(N_x\frac{\partial^2 w}{\partial x^2}+N_y\frac{\partial^2 w}{\partial y^2}+2N_{xy}\frac{\partial^2 w}{\partial x \partial y}\right) \quad (1)$$

Together with appropriate boundary conditions (BC), the exact analytical solutions can be found for small deformations in a direction perpendicular to the flat plate plane using classical separation of variables, eigenfunctions expansion, Laplace transforms or Green's functions. Boundary conditions can be represented by a simply supported edges, clamped edges, etc. Numerous analytical solutions with various BCs have been provided in [6]. Also the celebrated energy-method [6] can be utilized for quick practical estimation of critical loads under which the linear buckling instability grows without limit. The C-triplex plates are curved forming the cylindrical sections but for small curvatures (large radius of curvature) can be reasonably approximated by the flat-plate theory. It is clear that various sides of the plate can be exposed to alternating compression and tension per-unit-length forces. More information on bending, shearing and buckling of thin plates is to be found in [6, 8]. Using the computational FEA it is possible to evaluate stresses, strains and deformations of complicated structures such as multiple sandwich-type C-triplex panels assembled on a fuselage skeleton. Aeroelastic interactions are very important in aircraft design whereas they are mostly irrelevant in civil buildings (certain bridge designs being a notable exception).

A good discussion of flexural instability, buckling and short-wavelength inter-rivet wrinkling of thin panels for aircraft structures is provided in [8]. Additional useful information on stability of thin plates and design consideration for airplane wings and fuselages is also found in [7, 9, 10]. Due to non-isotropic nature of UD prepreg composite materials, the theoretical analysis of buckling instability of thin plates becomes quite involved.

It is noteworthy to say that the C-triplex design philosophy stabilizes the core thin panel and increases the overall rigidity. The simplified linear theory used to calculate buckling limits results in the following expressions [5]:

$$N_{critic}=\frac{\pi \cdot E \cdot J}{l_0^2} \quad (2)$$

$$\alpha = 1-\frac{N}{N_{critical}} \quad (3)$$

$$y_c = e_0\alpha - e_0 \quad (4)$$

$$y_c=\frac{5\cdot p \cdot l_0^4}{384 \cdot E \cdot J} \quad (5)$$

For $N=N_{crit}$ it yields:

$$p=\frac{384}{5\pi^2 l_0^2} \quad (6)$$

The symbols used in the above equations are given in Table 1 below. With this expression (Eq. 6), the lateral containment for the shell enclosing structure of the C-triplex panel can be quickly evaluated. For example for a 2 x 2 meter C-Triplex panel the lateral pressure $p$ is only 2 Pa (2 x $10^{-5}$ bar).

$$p=\frac{384}{5\pi^2 l_0^2}=\frac{384}{5\times \pi^2 \times 2^2}\approx 2\,[Pa] \quad (7)$$

However, detailed FEA gives more accurate and spatially-resolved results for final panel design and further optimization. Nevertheless, the containment structure for lateral pressure in the C-triplex panel could be truly slender.

**Table 1:** The symbols and units used to calculate the buckling limits of thin C-triplex panels.

| Symbol | Description | Unit |
|---|---|---|
| $N_{crit}$ | Critical Load | [N] |
| $E$ | Young's Modulus | [MPa] |
| $J$ | Moment of Inertia | [$mm^4$] |
| $N$ | Current Load | [N] |
| $A$ | Amplification Factor | [-] |
| $y_c$ | Deformation | [mm] |
| $e_0$ | Initial lateral displacement | [mm] |
| $P$ | Lateral linear load to be applied to restore the initial lateral displacement | [N/mm] |

**A note on LVARTM and C-Triplex**

LVARTM is a process using a rigid two-sided mold set that forms both surfaces of the panel. The basic idea with LVARTM is to put all the elements of the C-Triplex panel in a mold and obtain a panel already finished and ready for assembly, finishing (chalking compound application/honing) and painting. LVARTM seems to offer many advantages. The mold may be constructed from aluminum or steel, but low-cost composite GFRP molds are most commonly used. The two sides of the panel are clamped together to produce a mold cavity and sealed with a simple rubber liner. The distinguishing feature of resin transfer molding is that the reinforcement materials, a special fiber roving for improved resin penetration, inserts and core (usually closed cell foam) are placed into this cavity and the mold set is closed prior to the introduction of matrix material. Subsequently resin vacuum infusion takes place. The resin filling and the curing processes are performed at ambient temperatures to keep tolerances under strict control. The result is a sandwich panel finished on both side. The fiber content on the skin is less than 30% (usually around 10%), and it is not necessary to rework inserts for bolts and rivets. The correct placement of these elements is usually assured by cavities in the preformed core foam. The foam core can be manufactured by inserting a blowing agent in the primary liquid component that is poured into the cavity of the core mold. In our case the C-Triplex components can be assembled in a low cost GFRP mold and a room temperature curing process can be used. CFRP can be used for reinforcements. In naval applications the production cycle takes about 12 hours. The advantage of this approach is in a very good surface finish, tight tolerances (on the order of 0.1 mm) and the possibility to work the panels and the inserts with CNC to achieve tighter tolerances (on the order of 0.01 mm). This is possible due to the low carbon-fiber content of the skin. In fact a typical problem of high strength CFRP is that CNC is difficult, tool consuming, and the resulting tolerances are not tight (0.1 mm maximum). A very good drilling tool for CFRP lasts only for about 100 holes, while on steel a normal duration of a tool is for 1,000 holes. Additionally, LVARTM tooling like dies, vacuum machines, and resin-filling systems are very affordable. The main shortcoming is the space occupied by the dies.

**Conclusions**

We have demonstrated in this article that it is both desirable and possible to increase the use of composite materials in the construction of transport-category airplanes and particularly in the construction of fuselages. The reduction of the structural weight of any aircraft is an advantage not to be underestimated [14-19]. In fact, for every kilogram of structural weight savings, it is possible to reduce about 300 kg of fuel per year. This reduces not only the variable costs but also environmental emissions. The design solution involving C-triplex panels is based on the prefabrication concept shared with the positive experience and economics in construction of resident and business buildings. The C-triplex concept simplifies the aircraft assembly process and greatly reduces assembly time. The idea of manufacturing advanced composite panels with this design system considerably reduces the number of connections necessary for assembly again leading to a decrease in the structural weight of an aircraft. Additionally, the use of the technique of LVARTM as an alternative to that of the FW or "Fibre Metal Laminate", allows the serial production of fabricate completely interchangeable panels. The continuous on-line supervision and incorporation in the structure health-monitoring system further reduces maintenance cost and increases safety by performing much cheaper preventive maintenance when required.

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**9. NOMENCLATURE**

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| AVBM | Autoclave vacuum-bag molding |
| ATL | Automated Tape Laying |
| CFRP | Carbon Fibre Reinforced Plastic |
| CAA | China Aviation Administration |
| CNC | Computer Numerical Control |
| CS | EASA's aircraft certification standards |
| DSO | Design Service Objectives |
| EASA | European Aviation Safety Agency |
| FAA | Federal Aviation Administration (USA) |
| FAR | Federal Aviation Regulations (USA) |
| FEA | Finite Element Analysis |
| FW | Filament Winding |
| GLARE | Glass Reinforced aluminum alloy |
| HMV | Heavy Maintenance Visit |
| LVARTM | Light Vacuum Assisted Resin Transfer Molding |
| ICAO | International Civil Aviation Organization (UN agency) |
| NDT | Non Destructive Testing |
| UD | Uni-Directional |