Theodor Petrisor RUSOIU, Ionel SIMION

ASSEMBLY OF THE PRIMARY STRUCTURE OF AN AIRPLANE FUSELAGE

Abstract: *Aeronautic structures and their design have evolved over the years. The fuselage must be resilient, lightweight and able to connect the whole airplane. Also, the fuselage holds cargo transports, luggage and, most important, passengers. In the following paper we will deal briefly with the topic of fuselage assembly and how its primary structure is being manufactured. This paper gives a short introduction about the materials used in fuselage design and how the manufacturing techniques were modernised. In conclusion, we will focus on exemplifying the assembly process through the creation of a 3D CAD with the CATIA V5 Student Edition software.*

Key words: *Airplanes, Manufacturing, Assembly, Fuselage Design, Structures, Composite Materials.*

INTRODUCTION

The fuselage is the core of an airplane. It is the part in which all the other main components are mounted, it houses the pressurised zone of the passengers, contains the cargo departments, fuel tanks and the main wing structure. Moreover, all the aggregated systems, for example, hydraulics, ventilation, pressurisation, electric routing and aerodynamic control are installed inside the fuselage or they pass through it [3], [4].

Due to the dynamic development of aerospace industry, many industrial methods of design and assembly were practiced during the last century. However, the most practical model is composed by the classic frames and stringers, which got through a thorough optimisation until today. The stringers are the longitudinal components and the transversal components are called frames, together they hold the skin (Fig.).

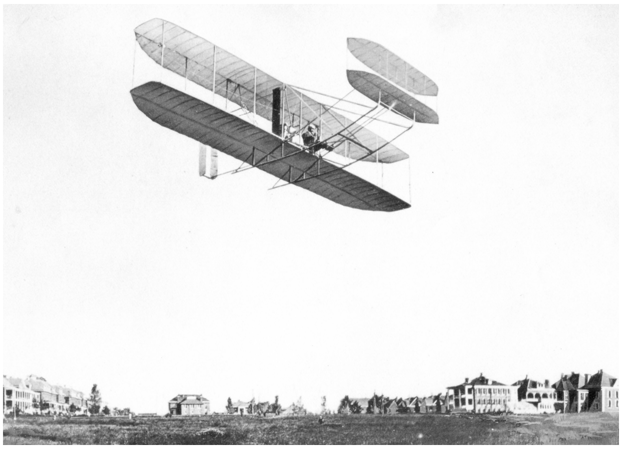

Fig. 1 Airplane from 1908 [11].

In the beginning of the XX century, aircrafts were built mainly by flight visionaries, who used construction materials available to their own time, starting from wooden structures wrapped around by textile canvases as aerodynamic skin. The weight and low material resistance was a major problem for that time.

With small advances during the First World War, the first industrial manufacturers used aluminium to create the aircraft structure, but the skin remained textile due the lack of aluminium alloys.

Major aviation developments were recorded starting during the Second World War and continued during the Cold War, when the main objective was combat resistance and flight speed. This period drastically changed mechanical engineering and laid the foundation for a modern aviation. Powerful jet engines, electronics and communication, radars, hydraulics, lightweight and resistant alloys were created for structures and skins [5].

Nowadays, the conventional aircraft structure has the frames, stringers and skin made of composite materials.

2. WHAT ARE COMPOSITE MATERIALS

The combination of two or more materials develops composite materials. The term "composite material" usually refers to fibre-reinforced plastics because this is by far the widest spread category of composite materials. The plastic is reinforced with fibres to make a light and strong material. The material, in which the fibres are enclosed, is called the matrix, while the fibres are used as reinforcement [7].

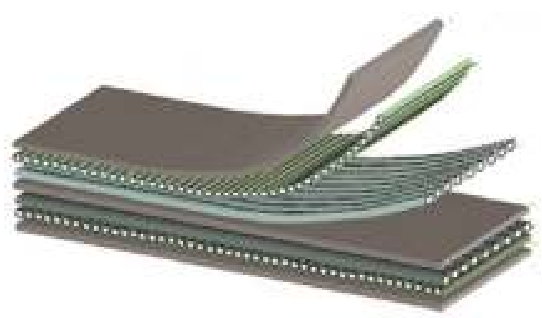

Fig. 1 Composite Materials Layers [6].

The big advantage of fibre-reinforced composites is that the stiffness and strength can be designed for specific loading conditions. If the loading of the composite component will be oriented in one direction, you can apply the fibre reinforcement mainly in that direction. It means that its stiffness and strength are not the same in every direction but can differ for every other direction in the material (fig. 2) [7].

This property is widely exploited in designing with composites starting with one single ply of fibre-reinforced plastic. A building block is called lamina or layer [7].

It is possible to tailor the stiffness and strength in different directions by stacking additional layers under different orientation angles (Fig. 3). The resulting pile of plies is called a laminate, built up of individual layers [7].

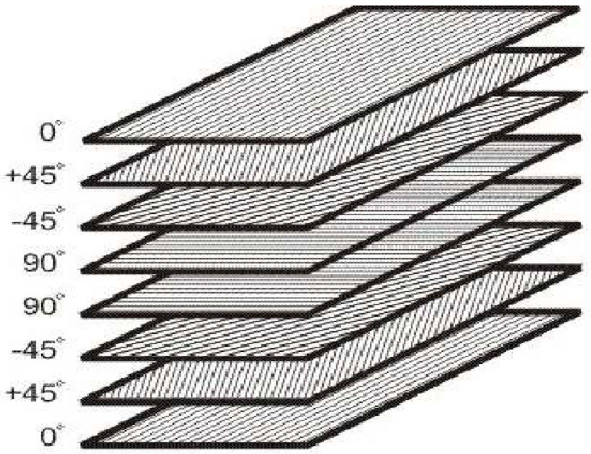

Fig. 3 Layering of Composite Materials at different angles [7].

A special type of composite laminate is the sandwich composite, where some of the middle layers of the laminate are replaced by a very lightweight core material, typically being metallic honeycombs, paper microstructures or foam [8].

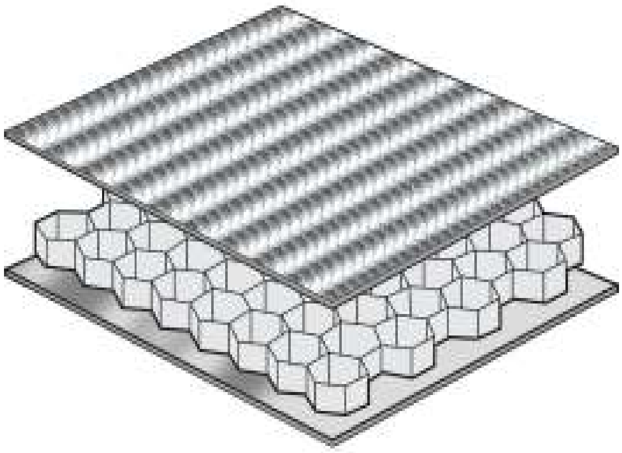

Fig. 2 Honeycomb Composite [8].

Sandwich composites are highly preferred because they are lightweight structures with a high bending stiffness and very resistant to impact and mechanical fatigue (Fig. 4). They can be found in ships, floor panels, aerospace structures, etc. [7]

3. MANUFACTURING

Generally, the structural components of the fuselage are made by combining the fibre composites with honeycomb structures in different ways. For example, the frames and stringers are made solely by carbon fibre composites with epoxy matrix, while the skin panels have in their design laminar composites with honeycomb cores.

The manufacturing of fibre composites parts starts with a basic mould, around which a special sewing machine positions every layer of carbon fibre textile and interconnects them at the designed angel (Fig.). In some cases, the carbon laminas are prefabricated with fibres positioned at 45 degrees from each other and they are positioned in the mould by highly specialised human operators.

Fig. 5 Carbon Fibers Circular Sewing Machine [5].

Moreover, after every layer of carbon fibre, a new ply of fibre glass is added for resistance. Sequentially, an epoxy adhesive is poured neatly over the two sheets of textiles to create the matrix. The process is repeated until there are enough layers to meet the required dimensions.

When the additive phase is over, the components are treated in autoclave curing facilities at an interval of 70-80 degrees Celsius to activate the matrix and to relax the strengthening fibres. Afterwards, the mould is removed and the composite material part is ready for finishing and inspection.

The skin and flooring panels receive a similar manufacturing technique; however, honeycomb cores are added in the middle of each panel to ensure a higher rigidity and flexibility. Due to the flexibility requirements of these panels the core design has an intricate design to meet the aerodynamic shape of the fuselage.

When the two exterior layers of the panel are manufactured and cured in the autoclave, a high viscosity adhesive is added on one side of each ply to be assembled with the honeycomb core. Also, the honeycomb structure has a higher thickness towards the connective edges to ensure stronger grip of the adhesive and better torsion resistance.

Composite materials used in fuselage structural parts are highly customisable and they ensure a wide variety of configuration and post processing. When the raw part is ready to be debited or drilled for electric routing, thermal insulation and mechanical fixation, the honeycomb structures are easy to be modified. Using abrasive water jet cutting techniques to meet the design standards of every aircraft component, the integrity of the composite material structure is maintained.

The cutting process is a product of a long research, due the difficulty of traditional cutting of composite materials. The classic drilling is not suitable, because it affects the properties of the intricate layers, the fibres can be damaged and the local resistance near the hole would be lowered. The laser techniques are not recommended; they can melt the matrix and modify its properties.

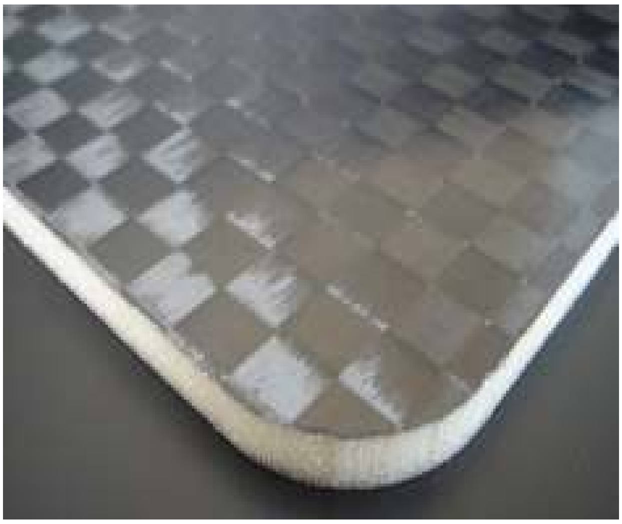

Fig. 6 Sandwich Composite Cut Out [9].

Therefore, the abrasive cutting with water jet is the best option, due to its precision and non-invasiveness of the surrounding area (Fig.). This technique is uses pressurised air to pulverise a mix of water and fine abrasive powders in small and precise quantities. The level of precision and effectivity of this method is implemented in many mechanical industries.

4. ASSEMBLY

Regarding the process of assembly, it has to be taken in consideration the logistic aspect. The plane is split in sections, which are assembled in different sites. Every site has its specific section to assemble. The suppliers and subcontractors that make the prefabricated parts are specialised for the activities performed in each site.

The final assembly takes place in a central assembly site, where the furniture and interior design is installed. This is the place where activities of painting and finishing the aircraft are taking place. Also, flight control is performed at final assembly line to ensure high quality product.

Usually, passenger aircrafts are divided as follows: Wings, Amperage (rear aerodynamic fins), Cockpit, Forwards and First Central Fuselage, Second Central and After Fuselage. The sites assemble the primary structures, electronics, hydraulics, aggregated systems, etc. When the sections are ready, they are transported towards the central assembly line.

To exemplify the assembly process of a fuselage, the following simplifying hypothesis was made as follows. The Central Fuselage section is represented. The frames are sectioned in six parts and held together by connector pieces. The fixation items are not shown in the CAD representation to conserve the computing time and resources [1].

Firstly, the assembly process starts by fixing the prefabricated parts of the frames in a support until the section is filled with frames (Fig. 8). The support is called Jig, both the frames and the jig follow the complex geometry of the fuselage.

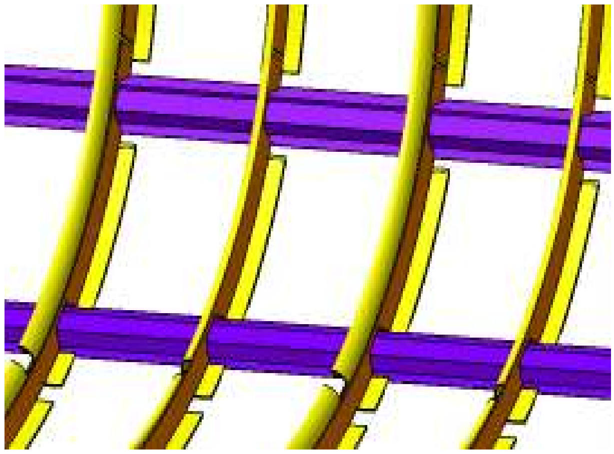

Fig. 4 Stringer Assembly.

Secondly, the connector parts are assembled on the frames, to ensure a stiff structure; they have to be fixed with special screws and hook that act as fasteners for the whole frame (Fig. 9). The connectors respect the frame’s shape.

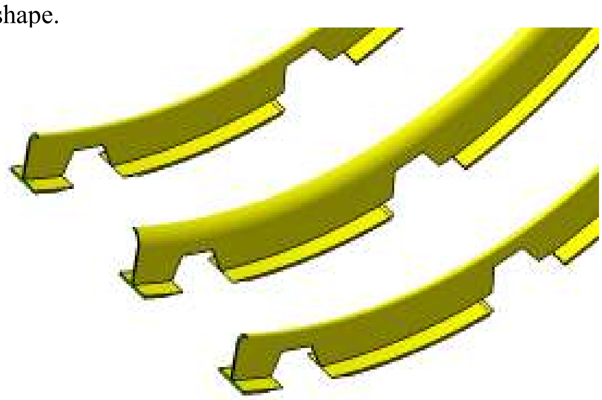

Fig. 5 Frames positioned for assembly.

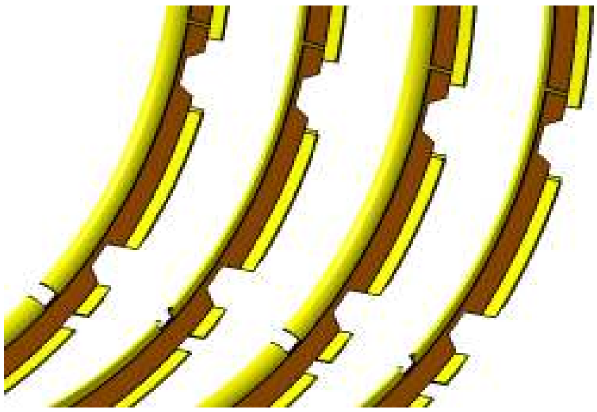

Fig. 6 Connector's Assembly on Frames.

Thirdly, the stringers are added in the next step to ensure the rigidity of the structure and to allow it to be transported to the next work station (Fig. 7).

Composite materials parts allow a quick installation of the stringer-frame system, fixations like clip nuts, rivets, clips, etc… are easy to put in place and to assemble. Usually, the stringers shape (omega type) is very versatile and simple to install.

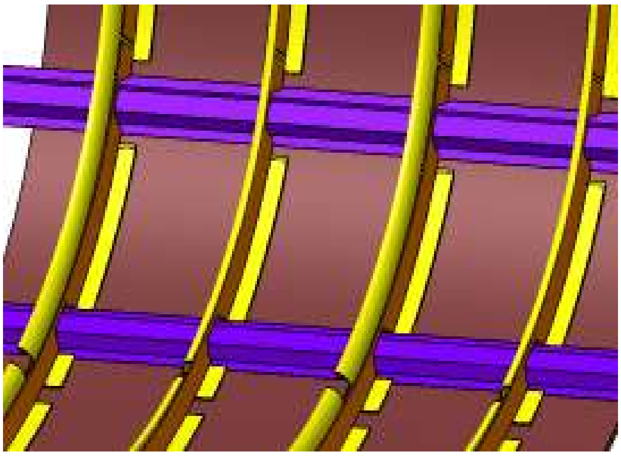

Fig. 8 Skin Assembly.

Fourthly, the skin is assembled (Fig. 10). While the frames act as transversal resistance components, the stringers take loadings on the longitudinal axis of the airplane. Therefore, the skin panels are fixed with rivets and screws in both frames and stringers.

Finally, the primary structure assembled (Fig. 11). It was represented holistically with respect towards the simplifying theories applied. The assembly process implies many aspects inside an aviation factory, starting from the design phases and following with the assembly stage. After taking in consideration work productivity and industrial optimisation of production, the exemplified model is a very simplified version.

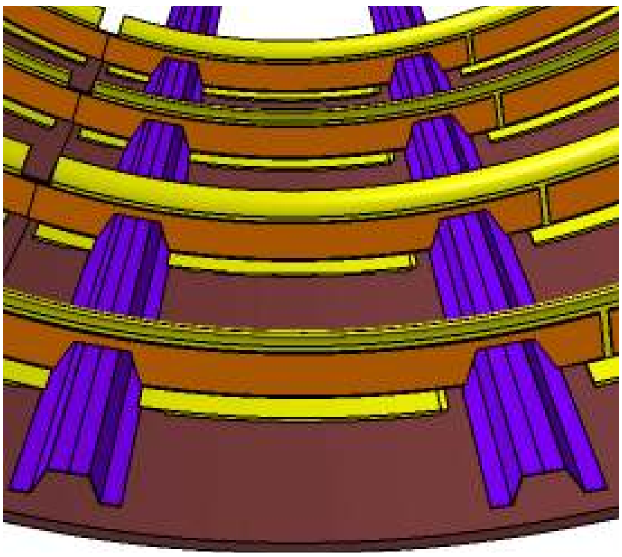

Fig. 7 Final Assembly.

5. CONCLUSIONS

Currently, the aircraft manufacturers have a wide logistic and vast supply chains of subcontractors that produce the small parts, which are afterwards are assembled in specialised manufacturing plants.

The practical model of building subassemblies in different places around the globe and putting them together in one central assembly line has major financial benefits. The design management takes into consideration the different production prices, work force specialisation and know-how of each particular zone when a new aircraft is being designed.

In conclusion, the manufacturing and assembly processes of the fuselage were exemplified with a CAD model. The composite materials that are used in the production of aeronautic parts were described.

The fuselage structure presented in this paper was simplified, regarding the applied hypothesis in order to show the basic steps of a fuselage structural assembly in a simple manner.

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Authors:

Student Eng. Theodor Petrisor RUSOIU, University Politehnica of Bucharest, Romania, Faculty of Aerospace Engineering, Department of "Engineering Graphics and Industrial Design", tel: +40 747 983 958, E-mail: theodor.petrisor.rusoiu@gmail.com

Ph.D. Professor Ionel SIMION, University Politehnica of Bucharest, Director of Department "Engineering Graphics and Industrial Design", Faculty of Aerospace Engineering, E-mail: ionel_simion@yahoo.com