DEVELOPMENT OF CARBON FIBER REINFORCED PLASTIC FITTINGS TO ATTACH RODS IN CENTRAL WING BOX OF AIRBUS AIRCRAFT

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Abstract

Central wing box of Airbus A350 eXtra Wide Body aircraft contains fittings to position rods used to stiffen this highly-loaded structure which is used as a petrol tank. Initially designed in aluminum-lithium, a weight saving campaign considering cost aspects led to develop carbon fiber reinforced plastic fittings based on an idea and proposal from SKF Aerospace. A proprietary patent of unfolding concept permits a high load transfer thanks to fibers working in tension and resin in compression only, in an out-of autoclave technology. In this study, many specimens were manufactured in order to be tested. Inspectability of the parts has been proofed with two complementary processes: standard ultrasonic for the web, and X-rays tomography for the sole. The material allowable values take into account the possible defects that cannot be detected. Dedicated test rig was developed in order to have a representative environment to mechanically test different fitting geometries, in static and fatigue. Wet ageing was justified by using a knock-down factor as time to saturate was excessive. Influence of temperature was checked and effect of lightning strike has been verified. Very satisfying test results shows this technology allows further weight saving by reducing web thickness on some fittings and reducing associated rod ends width.

1. Introduction

Central Wing Box (CWB) of Airbus A350 eXtra Wide Body aircraft (Fig. 1) contains fittings to attach rods used to stiffen this highly-loaded structure which is used as a petrol tank. These fittings were initially designed in aluminum-lithium alloy. Weight saving campaign led to consider carbon fiber reinforced plastic (CFRP) as an alternative solution for many of these fittings (Fig. 2, 3 and 4).

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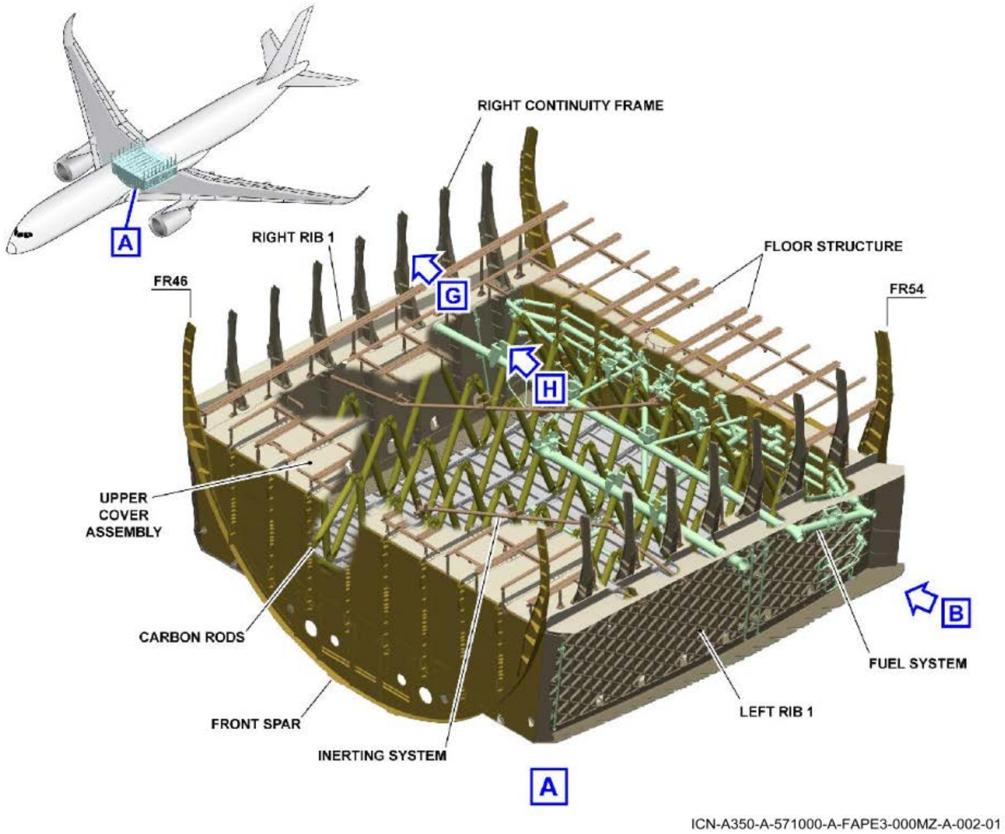

Figure 1. Location and view of Central Wing Box (A) in A350 aircraft with web of rods.
(source: Airbus A350 aircraft maintenance manual)

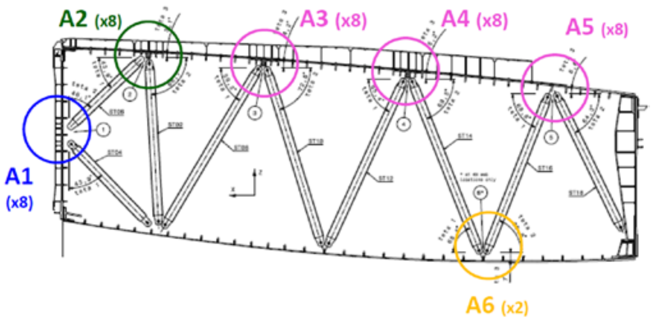

Figure 2. Central Wing Box cross-section with location of CFRP fittings (from A1 to A6) and associated number.
(source: Airbus)

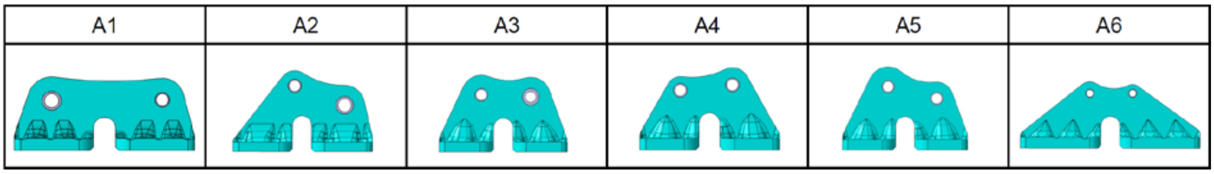

Figure 3. Fitting geometries in function of location A1 to A6.
(source: SKF Aerospace)

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Figure 4. Aluminum-lithium fitting design (left) and CRFP design (right) for A1 location.
(source: Airbus and SKF Aerospace)

2. Design

SKF Aerospace proposed an innovative design solution in order to achieve some weight saving. A proprietary patent of unfolding concept result in an optimized design, consisting on transferring tension load only to fibers and compressive load to resin. Web is constituted of uni-directional tapes layered in a quasi-iso stack. This web stack is running to the sole, where the base is completed by short fibers (Fig. 5). Epoxy resin matrix is the same for the whole part.
Environment, health and safety aspects were checked: change from aluminum-lithium to CFRP does not present any concern. Matrix material is well known by Airbus and a preliminary knock-down factor is used to take into account influence of kerosene. A kerosene resistance test is foreseen during the qualification test campaign to refine this knock-down factor.

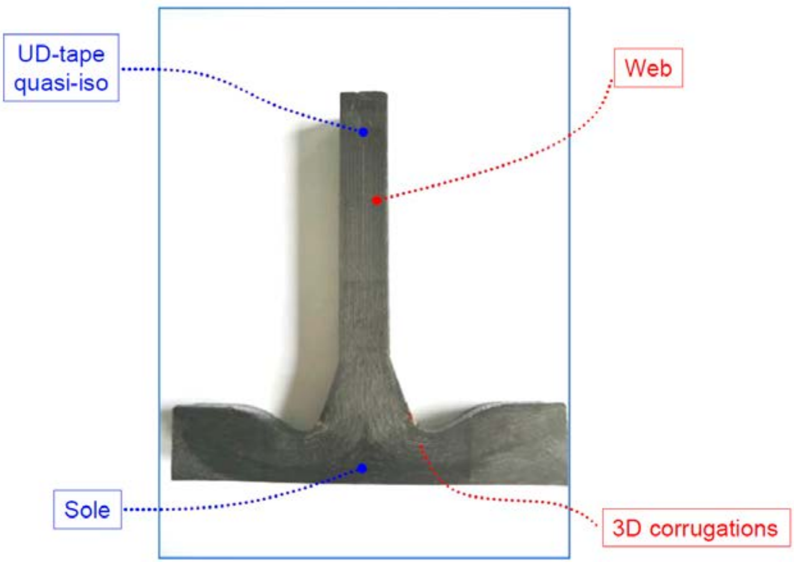

Figure 5. Cross-section of fitting with different areas.
(source SKF Aerospace)

2.1. Manufacturing

Manufacturing of such part does not require autoclave. Web is constituted by pre-impregnated unidirectional fibers stacked-up in a quasi-is direction. Sole is constituted by short fibers via the Bulk Molding Compound (BMC) process. Web and sole are preformed separately and then assembled into a mold for curing. After curing and machining, Ti-6Al-4V alloy bushes are room temperature bonded in web (Fig. 6) in order to withstand elevated bearing stress induced by pin from rod assembly. Bush thickness is customized to accommodate stress level.

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Process capability measurements led to correction of some tooling in order to reach an acceptable capability level.
For assembly of the fitting to surrounding structure, hemispheric Ti-6Al-4V alloy washers are installed in "countersink" areas in sole (Fig. 7).

Figure 6. Ti-6Al-4V bush in fitting.
(source: Airbus)

Figure 7. Corrugated areas around holes in sole to receive hemispheric washers for assembly.
(source: Airbus)

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2.2. Inspectability

Inspection is made in two steps, corresponding to each part of fitting and associated technology. Web is checked by conventional ultra-sonic inspection whereas sole is checked by X-rays tomography (Fig. 8). Delamination, porosity and resin rich area are checked and compared to acceptable threshold. A visual inspection is also performed.

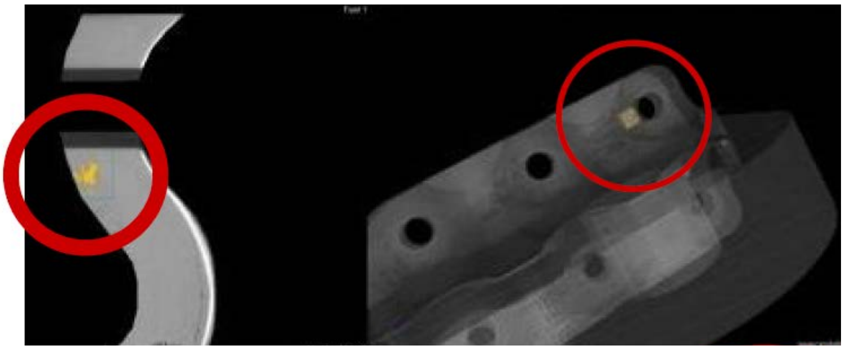

Figure 8. Example of X-rays tomography inspection with porosity around hole in sole.
(source: SKF Aerospace)

2.3. Weight saving compared to aluminum-lithium alloy

Forty-two aluminum-lithium fittings are replaced by CFRP fittings. Design is adapted to material in order to get the best advantage of this technology. The associated weight saving is around 19 kg for A350-1000 and 28 kg for A350-900. Considering the mechanical results presented hereafter, further weight saving can be done by reducing web thickness and redesigning rod ends. This would lead to at least 24 kg weight saving for A350-1000.

3. Testing

3.1 Specimens

Several geometries are manufactured, corresponding to the different locations and load direction due to rod position (Fig. 9).
The specimens are manufactured with defects corresponding to the maximum internal defects allowed (porosity, delamination, fiber waviness). Impacts are also performed, corresponding to installation threats and in-service usage: 35 J (barely visible impact damage) and 90 J (visible impact damage) on sides and edge of web (Fig. 10).

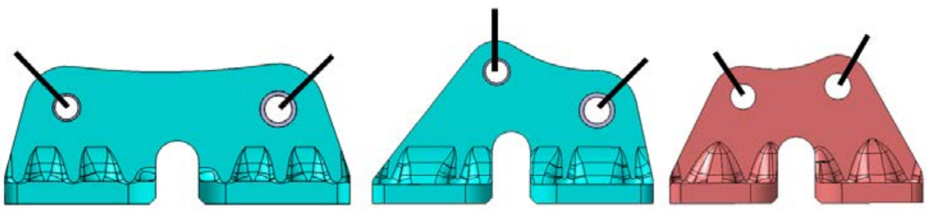

Figure 9. Different geometries of tested specimens and loads orientation.
(source: SKF Aerospace)

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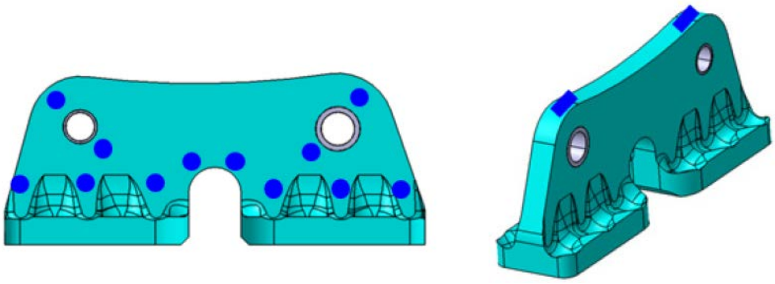

Figure 10. 35 J impact locations (blue areas).
(source: SKF Aerospace)

3.2 Test bench

A dedicated test bench is designed by SKF Aerospace and Airbus. Two adjustable actuators representing load introduction by rods allows any orientation in order to be representative of different fitting positions in central wing box (Fig. 11).

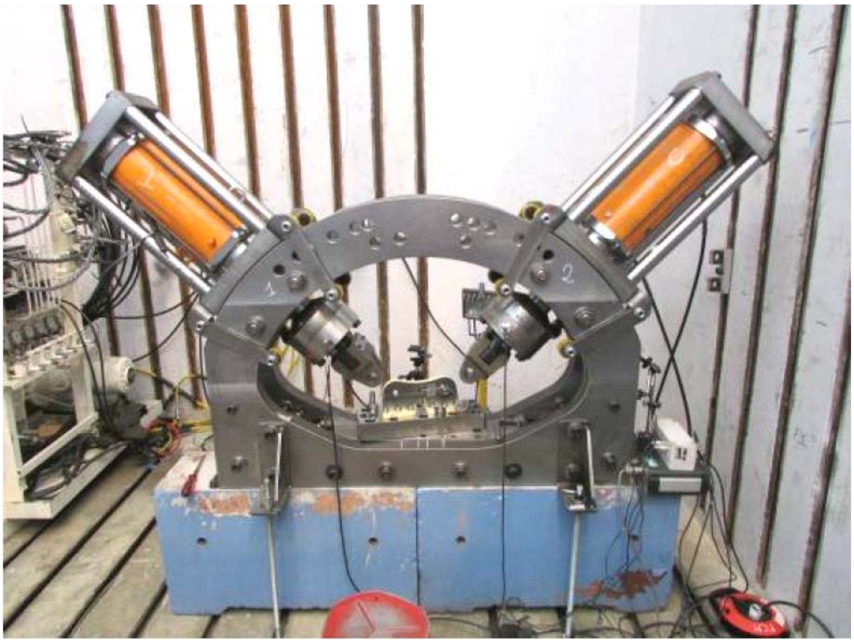

Figure 11. Different geometries of tested specimens and loads orientation.
(source SKF Aerospace)

3.3 Stiffness measurements

Stiffness of the CFRP fitting is measured in tension and compression in order to compare to the aluminum-lithium one. These results are implemented in the global model and it shows such change of material/design has low influence on the load distribution. Rods are safe because such load variations are covered by a design factor applied to rods.

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3.4 Test sequence

- A non-destructive investigation is performed on the specimen in the "as-new condition" in order to have a reference prior mechanical testing.
- Fatigue spectrum is applied to the specimen thru the holes located in web to stress the fitting. One actuator applies compressive stress whereas the other actuator applies tensile stress simultaneously (Fig. 12). Minimum load to maximum load ratio is 0.1 for both actuators.
- A second non-destructive investigation is performed in order to check for any propagation of initial defects.
- Static test is performed up to limit load then ultimate load, taking into account the following knock-down factors: scatter effect, temperature (-55°C to +80°C) and wet ageing*. Different load cases lead to different loads directions, depending on fitting location.
- Then load is raised until failure in order to check failure mode, compare with calculation, and identify margins.

* *Wet ageing of specimens prior testing is not performed due to excessive time to saturate the elevated web thickness. Instead, an Airbus knock-down factor is used for this known resin.*

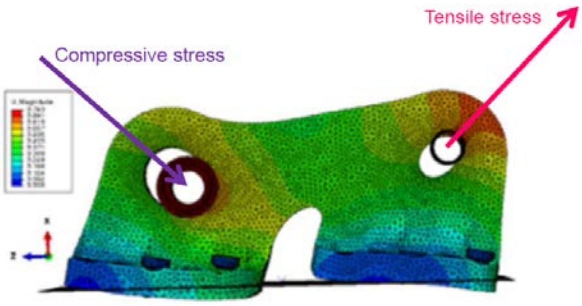

Figure 12. Loads directions for fatigue spectrum shown on stress model exaggerating deformations: compressive (left) and tensile (right).
(source SKF Aerospace)

3.5 Test results

Fatigue cycling is not detrimental to the specimens. All the specimens withstand the static loads, both limit and ultimate: there is no detrimental deformation at limit load, and no failure at ultimate load. Failure mode for margin identification are in net section and bearing (Fig. 12).
Very satisfying test results shows this technology allows further weight saving by reducing web thickness on some fittings and reducing associated rod ends width.

Figure 12. Failure modes: net section (left) and bearing (right).
(source SKF Aerospace)

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4. Further steps

4.1 Assembly

Assembly trials are currently performed in Airbus plant. Many parameters are taken into account: assembly gap (between sole and substructure), drilling grid positioning, drilling, hole diameter measurement, installation of hemispheric washers, installation of fasteners and tightness. For the moment there is no problem identified.

4.2 Lightning strike

Lightning strike protection requirements within the fuel tank are checked with the CFRP version of fittings. Fitting is attached to a representative panel of Central Wing Box and a pin representative of rod end is installed in one of the fitting bush (Fig. 13). Several specimens are tested using different configurations for such assembly: varying torque for screws/nuts, interfay sealant and with/without overcoat sealant on fastener. Electrical current is applied between rod pin and panel, with different intensity.

Figure 13. Example of specimen for lightning strike test.
(source: Airbus)

All the specimens successfully passed the test for all the intensities applied. There was no finding regarding voltage sparking (sparks due to difference of voltage between two parts due to insufficient electrical conductivity), outgassing or explosion of gas cell (emission of gas due to excessive heating). Junction between rod and panel is inherently safe, and CFRP fittings are validated from a lightning point of view.

5. Conclusion

SKF Aerospace proposed an innovative design for fittings used in central wing box of Airbus A350XWB aircraft. This CFRP design is very promising regarding weight saving. Therefore an extensive testing was deployed in order to assess capacity of such design. Manufacturing capability and inspectability has been verified. Then mechanical testing was checked, taking into account potential defects. Lightning strike aspect has been cleared, and assembly trials are currently investigated in Airbus plant. Further design optimization leading to more weight saving is being investigated.

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