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Team 519: Composite Airframe Life Extension

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Customer Needs

The customer needs were determined by asking NGC questions about the current part. In this case, the customer needs are more accurately called requirements; the composite part absolutely must withstand all the same conditions that the aluminum part already does. The customer requirements can be broken into two categories: functional and environmental.

The function of the part is the primary purpose of the part: what the part does in the airframe. It will determine how strong the part must be and the size of the part. This information is critical to completing the first key goal, determine stresses.

The environmental requirements describe the conditions the part must survive in. They do not represent the primary purpose of the part but describe the environmental conditions the part must withstand.

Functional Requirements.

NGC was asked about the specific dimensions and loading conditions of the part. Their response was that they did not have a specific C channel in mind. They were more interested in C channels as a class of components rather than one specific C channel in a particular location in the airframe. NGC uses standard dimension C channels of several sizes in many locations in the aircraft. The team selected the smallest standard size of c channel to design a replacement for. The smallest C channel that could be used in the E-2 has a web width of 2”. The smallest standard C channel with this web width is the Aluminum Association ABC, shown below.

As strong as aluminum.

It needs to have similar mechanical characteristics such that it can withstand the same loading conditions as aluminum. NGC wants to be able to remove aluminum channels and replace them with composite channels without having to redesign the airframe. Note that this means the team does not have to contend with safety factors because the loading of the channel and strength of the channel is not changing.

Easy to install.

Aluminum C channels come in standard sizes. NGC wants the part to be easy to incorporate into an airframe without having to redesign existing components. The part should have a similar size and geometry to a standard aluminum size. It should also have a simple attachment method, preferably holes for using traditional fasteners.

Competitive price.

The principle disadvantage of composites is the high price, relative to traditional components. NGC wants the part to be priced competitively, relative to aluminum. It is unlikely that composite parts will be as cheap as aluminum; therefore, any design more expensive than aluminum should have some redeeming qualities to justify the additional cost.

Environmental Requirements.

When asked about the operational conditions, NGC provided a list of the requirements for the aluminum part and the testing methods that were used to certify its use. It is unlikely that the team will be able to afford to do every test listed, so the team will have to down select to the most important and most feasible tests. Table 1 includes the list of each test done on components

in the E-2. Not all the requirements are of equal weight; withstanding operational temperature is clearly more important than fungal resistance, for example.

Table 1
Environmental Requirements

Requirement	Limits	Recommended Test Procedure
Temperature: Operating	-20 to +55 C internal -60 to +55 C external	MIL-STD-810E Methods 501.3 and 502.3 Procedures II with modifications.
Temperature: Non-Operating	-40 to +85 C internal -60 to +85 external	MIL-STD-810 Methods 501.3 and 502.3 Procedures I with modifications.
Temperature Altitude: Operating	-20 to +55 C at and up to 35K ft internal -60 to +55 C at and up to 35K ft external	MIL-STD 810C Method 504.1-II, Cat 5, steps 5 and 10 with modifications
Thermal Shock: Non-Operating	-20 to +55 C for internal	MIL-STD-810E Method 503.3 with modifications.
Rapid Decompression	Continuous operation of equipment within pressurized volume while decompressing from 5K to 35K ft.	MIL-STD-810E Method 500.3 Procedure III with modifications
Humidity: Operating	Up to 100% RH including condensation.	MIL-STD-810E Method 507.3 Procedure III
Vibration: Operating	Functional and endurance levels are derived from flight test data and are location dependent within the aircraft.	MIL-STD-810E Method 514.4 Categories 4.
Shock	20 G, 11 ms operational 40 G, 11 ms crash safety	MIL-STD-810E Method 516.4, Procedure I and V
Sand and Dust: Non-operating	Withstand effects	MIL-STD-810E Method 510.3, Procedure I or III, and II

Fungus	No fungi nutrient materials to be used.	MIL-STD-810E Method 508 OR analysis
Salt Atmosphere: Non-operating	Withstand effects	MIL-STD-810E Method 509.3
Explosive Conditions	Equipment shall operate when exposed to a flammable atmosphere.	MIL-STD-810E Method 511.3, Procedure I

Temperature

There are three different temperature sets, which can be condensed into a single temperature range using the most extreme values. Polymers have lower temperature resistance than metals, so this is an area that will need to be validated.

Thermal Shock

Thermal shock causes failures in materials because the strain caused by thermal expansion or contraction becomes too much for the material and it fractures. Brittle materials tend to be more susceptible to thermal shock because they cannot absorb much strain, compared to ductile materials. Materials with extremely high stiffness can also absorb thermal shocks. CFRP behave as brittle materials with very high stiffness, so this may be a relevant test, depending on the thermal loading conditions.

Rapid Decompression

There are probably not facilities available to test this, and a structural component is probably not particularly vulnerable to rapid decompression.

Humidity

A naval aircraft will be continually exposed to a humid environment when on deployment, making this a relevant consideration. Condensation can cause swelling degradation in polymers, making this a relevant test. If the polymer is not susceptible to swelling, then this is an area where the composite might be more resistant to the corrosive side effects of hudity compared to metals.

Vibration

Due to the complex structure of composites, this will be an area that can probably only be validated experimentally, and it is possible that a composite could fail when exposed to the large variety of vibration frequencies.

Shock

This may be relevant, but there are not faculties available to test this, and it is not part of regular operational conditions.

Sand and Dust

This is not particularly important for an unexposed structural member with no moving parts or small pieces. It is probably reasonable to elect out of this test.

Fungus

This is not particularly important to test, and the criteria of simply not using a fungi nutrient material is probably simple to confirm.

Salt Atmosphere

This is very important for long life in a naval aircraft since it will be continually exposed to a salt atmosphere. This, along with humidity resistance are the secondary advantages

composites offer compared to traditional metals. Polymers are generally not susceptible to the electrochemical corrosion caused by exposure to a salt atmosphere.

Explosive Conditions

This is another criterion which is probably less important, does not represent operational conditions, and a facility to test this are probably not available.

Customer Needs Statements.

The formal customer needs statements are a synthesis of the product requirements. They state “what” the shelf does, not “how” it does it. They are listed using positive phrasing, avoiding the terms “must” and “should”. The statements are presented in a ranked order with the most important statements coming first.

1. ***Withstands loading***

The part has the same strength as an aluminum part of the same size and can be loaded in the same manner as the aluminum part.

2. ***Withstand the environment***

The part does not break under the operational conditions and will last a long time even when exposed to those conditions.

3. ***Interchangeable with aluminum part***

The composite part can easily be placed into the same position in the airframe as the aluminum equivalent.

4. ***Low Weight***

The composite part must not weight more than the aluminum equivalent.

5. Competitive price

The part is affordable and adds enough value compared to aluminum to be worthwhile.