



AEROSPACE INFORMATION REPORT

AIR5552™**REV. A**

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Superseding AIR5552

(R) Development and Qualification of Composite Landing Gears

RATIONALE

This revision incorporates new content in Sections 4 and 5 regarding thermoplastic/thermoset considerations and design/manufacturing considerations.

1. SCOPE

This SAE Aerospace Information Report (AIR) provides general guidance for design considerations and qualification in endurance, strength, and fatigue of landing gear using composite components as principle structural elements.

The information discussed herein includes the development and evaluation of design data considering the potential for imbedded manufacturing defects, manufacturing process variations, the component operating environment, potential damage threats in service, rework and overhaul, and inspection processes.

This AIR mainly discusses the use of thick composites for landing gear structural components. Considerations and recommendations provided in this AIR may therefore differ greatly from considerations and recommendations found in widely accepted composite design references such as CMH-17 and Advisory Circulars such as AC 20-107B.

1.1 Purpose

The purpose of this AIR is to provide general guidance in the qualification of composite components for landing gears. Compliance with this report is not considered approval for installation on any category aircraft or helicopter.

The Certifying Authority for the platform for which the equipment is intended may be consulted for concurrence with the approaches proposed herein as an acceptable qualification demonstration for composite landing gear components.

1.2 Application

This AIR is applicable to the qualification of the composite landing gear structural elements in strength, fatigue, and endurance. The current version of this document focuses on the use of Polymer Matrix Composites but might also be applicable for other composite materials such as Metal Matrix Composites, although they are not explicitly discussed herein.

Compliance with this information report by manufacturers, installers, and users may be used as a means of assuring that the equipment will have the minimum capability to satisfactorily perform its intended function(s).

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1.3 Composite Design References

In the development of this AIR, close interaction is sought with other composite guideline development such as within the CMH-17 and AC 20-107 committees.

It is noted that the majority of documentation on composite materials concerns thin-walled structures. The application in landing gear principle structural element primarily focuses on thick-walled structures.

1.4 Further Development of This AIR

It is recognized that the guidance provided in this document on composite application to a landing gear principle structural element is general in nature and limited in scope. It is the intent that this document will be further developed over time where active feedback from industry and authority specialists is sought to expand the scope to other category aircraft and provide more specific guidance to composite component development in landing gear principle structural elements.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws or regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (U.S. and Canada only) or +1 724-776-4970 (Outside U.S. and Canada), www.sae.org.

AS1241 Fire Resistant Phosphate Ester Hydraulic Fluid for Aircraft

2.1.2 Code of Federal Regulations (CFR) Publications

Copies of these documents are available online at www.ecfr.gov.

14 CFR Part 25 Airworthiness Standards: Transport Category Airplanes (§25.301 through 307, §25.471 through 25.519, §25.571, and §25.723 through 25.729)

2.1.3 EASA Publications

Available from European Union Aviation Safety Agency, Konrad-Adenauer-Ufer 3, D-50668 Cologne, Germany, Tel: +49 221 8999 000, www.easa.europa.eu.

AMC 20-29 General Acceptable Means of Compliance for Airworthiness for Products, Parts and Appliances

2.1.4 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

AC 20-107B Composite Aircraft Structure

AC 23-13A Fatigue, Fail-Safe, and Damage Tolerance Evaluation of Metallic Structure for Normal, Utility, Acrobatic, and Commuter Category Airplanes

AC 25.571-1D Damage Tolerance and Fatigue Evaluation of Structure

DOT/FAA/AR-03/19 Material Qualification and Equivalency for Polymer Matrix Composite Material Systems

2.1.5 Other Publications

CMH-17 Composite Materials Handbook

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (U.S. and Canada only) or +1 724-776-4970 (Outside U.S. and Canada), www.sae.org.

AIR5914 Landing Gear Fatigue Spectrum Development for Part 25 Aircraft

AIR6827 Design Considerations for Composite Secondary Structure on Landing Gear

ARP1311 Landing Gear Structures and Mechanisms

ARP5644 Landing Gear Shock Absorption Testing of Civil Aircraft

2.2.2 Battelle Memorial Institute Publications

Copies of these documents are available online at www.mmpds.org/purchase-handbook.

Metallic Materials Properties Development and Standardization (MMPDS) Handbook

3. APPROACH

In order to define the strength and fatigue capabilities of composite components, their properties are determined by structural analysis and/or test. Typically, a pyramid or building block approach is employed where analyses are combined with tests at various levels of structural complexity. Going up this pyramid, the number of test specimens decreases, while the test complexity increases. During a program, these building block levels are linked with supporting technologies and design considerations. This is depicted in Figure 1.

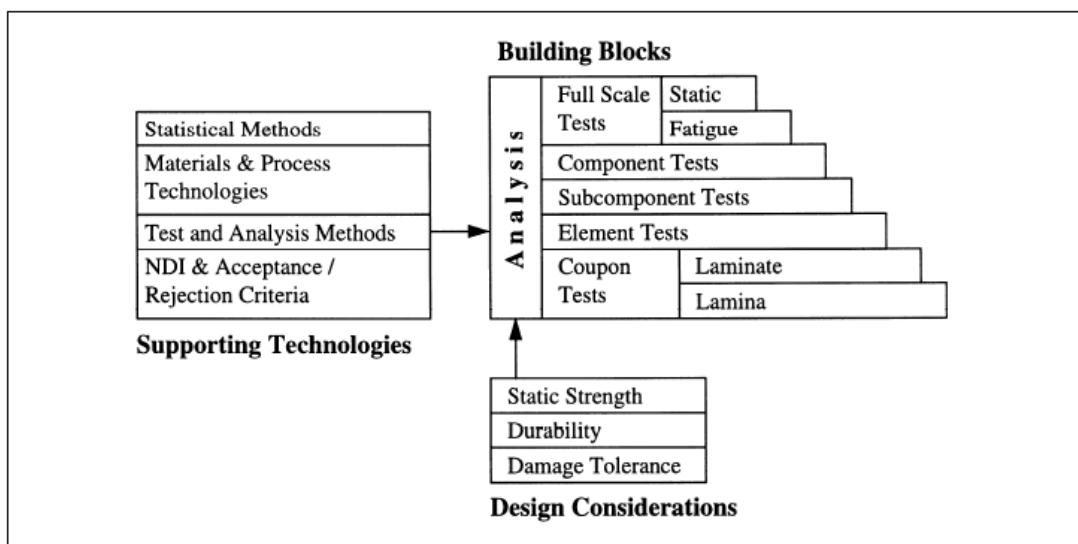


Figure 1 - Building block approach from CMH-17

Simple coupons or specimens are tested at the lowest level to statistically determine the material strength and stiffness allowables. Once the simple coupon values are determined, more complex multidirectional coupon properties are developed by test until ultimately the component level properties are defined. The building block approach could include the critical service environmental conditions in deriving the material properties and allowables. The number of tests is sufficient to ensure statistically significant results.

Because of the complex, anisotropic mechanical response of composite materials, modifying factors as traditionally used in metal components, like stress concentration factors found in handbooks, cannot be used. Instead, the properties of critical details are substantiated by using structural element or sub-component tests representing local composite architecture and design details. Also, scaling of structural elements as seen in metal design solutions is generally not possible in composite designs. Instead, extensive testing and analyzing is required.

Although the building block approach is widely acknowledged, details are far from universal and may be program and component specific. Figures 2 and 3 depict a typical building block strategy for aircraft defined in CMH-17.

For more information on the building block approach, refer to CMH-17.

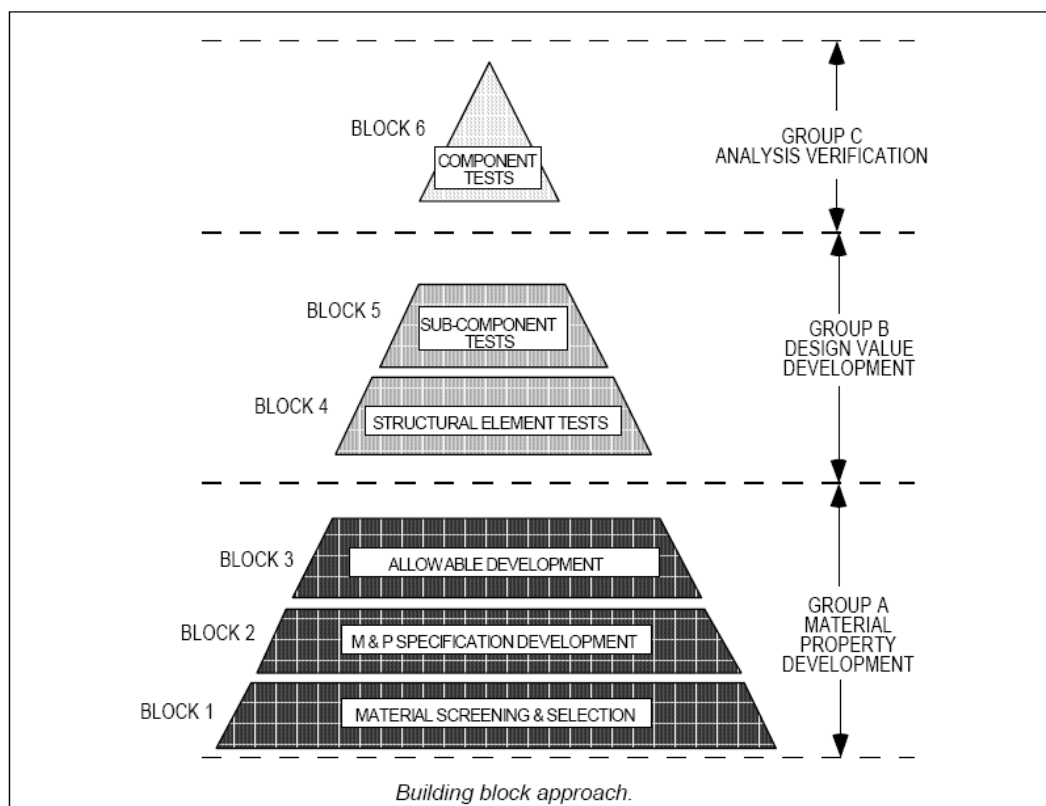


Figure 2 - Typical building block approach for aircraft (from CMH-17)

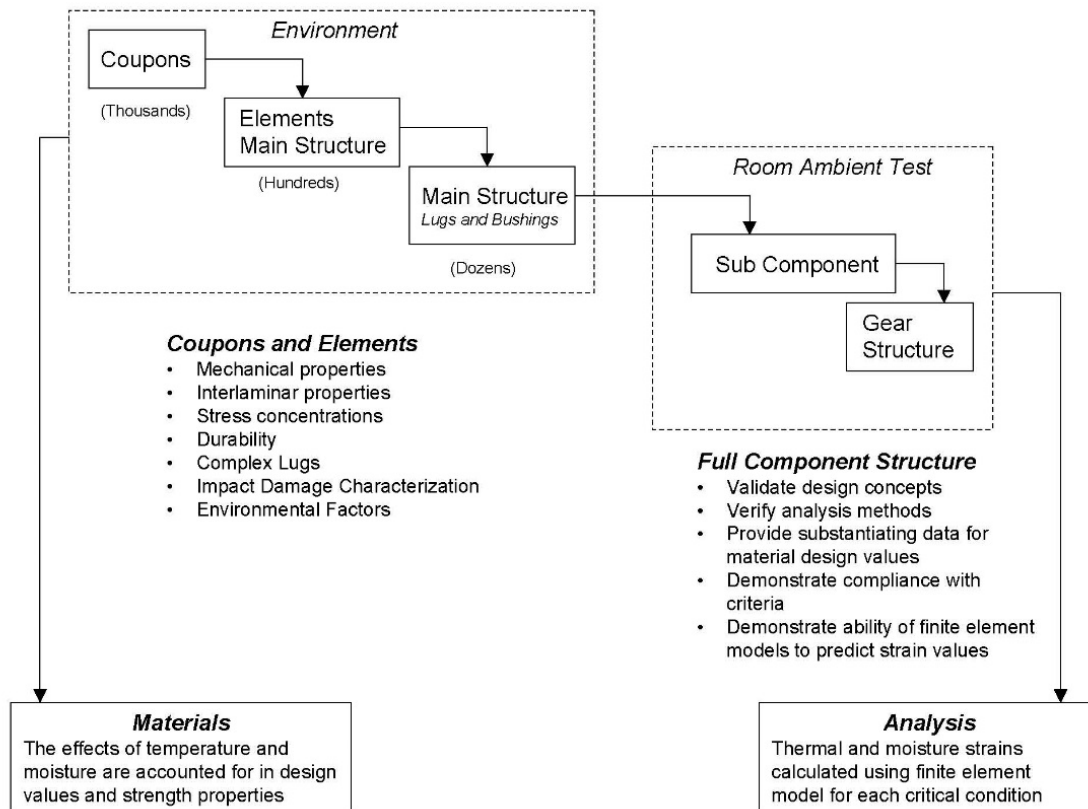


Figure 3 - Building block approach for aircraft landing gear (adapted from CMH-17)

4. THERMOPLASTIC VERSUS THERMOSET COMPOSITES

Polymer matrix composites use one of two primary resin systems: thermoplastic or thermoset. Each type has its particular advantages and uses. The material system choice, application, and manufacturing technique will drive which resin system is used. Traditional thermoset laminates have a long-standing history in the aerospace industry, but thermoplastics are starting to gain market share due to their increased toughness, joining capabilities, and less stringent storage requirements, among other benefits.

4.1 Thermoset Composites

The matrix within a thermoset composite is a resin which undergoes an irreversible chemical reaction during cure. Thermosets generally need to be refrigerated prior to use to prolong storage life but typically process at lower temperatures than thermoplastics. Thermoset composites generally exhibit high strength but tend to be brittle, yielding comparatively poor impact capabilities. When exposed to heat, thermosets will degrade, and potentially char, but will not melt. Thermosets are usually chosen for high temperature applications.

4.1.1 Resin Systems

Most thermoset composite parts use polyester or epoxy resins. Other examples of thermoset resins used in reinforced form are phenolics, silicones, bismaleimides, and polyimides.

Thermoset polymers usually undergo three stages of cure:

- A Stage: The resin and curing agent are mixed, but the chemical reaction has not yet started.
- B Stage: The chemical reaction has started, and the viscosity and tackiness of the mixture have begun to increase.
- C Stage: The resin is completely cured.

Hence, the final structure of thermoset is constructed during processing, creating an internal 3D structural network of highly cross-linked polymer chains. The final product cannot be thermally reformed and is insoluble.

4.2 Thermoplastic Composites

The matrix within a thermoplastic composite melts at a given temperature and is able to be processed at or above that temperature. Upon cooling, the thermoplastic solidifies, but it is capable of being remelted into liquid form. Thermoplastics can be stored at room temperature. Thermoplastics tend to require higher processing temperatures but generally exhibit higher toughness and better chemical resistance than thermosets. Given the remelt capability, thermoplastics are more suitable for recycling but are also limited to lower temperature applications.

Table 1 - Relative comparison between thermoplastic and thermoset matrices

NOTE: "+" IS FAVORABLE

Property/Characteristic	Thermoplastic	Thermoset
Storage Requirements	+	-
Shelf Life	+	-
Cost	-	+
Ease of Processing	+	-
Toughness	+	-
Remelt Capability	+	-
Temperature Capability	+	++
Material Strength/Stiffness	+	++

5. COMPOSITE DESIGN AND MANUFACTURING

Composite components may offer cost and weight savings over traditional metallic components. Often composites are thought to be more expensive than traditional metallic components due to high initial tooling costs and the potential for nonrecurring engineering associated with design/redesign of a component. An all-inclusive business case is typically done as part of the design process to ensure component costs are accurately represented. Composites may afford the opportunity to eliminate protective coatings (i.e., corrosion coatings/primers), combine multiple components into one (part number reduction), and decrease required rework. Their increased fluid resistance and noncorrosive properties may decrease replacement or repair costs across the component life cycle. The ability to amortize tooling costs is also normally an option to be considered in this process.

Interface geometry, fastening or joining techniques, and design loads play a key role in defining an acceptable design solution. Galvanic interaction with metallic interfaces, increased edge distances relative to loading, and anisotropic material properties are usually considered.

5.1 Component Design Considerations

There are a number of design implications to evaluate when considering utilizing composites for landing gear components.

5.1.1 Advantages of Composites

The following sections summarize some of the advantages to be realized when utilizing composites for landing gear components.

5.1.1.1 Weight Savings

Due to their relatively low density, composites in general offer weight savings relative to metallic components of comparable volumes. The density varies by the particular composite material, but a typical carbon composite (approximately 60% fiber volume [FV] fraction) density is approximately 60% that of aluminum. The weight reduction achieved depends on several factors, including the method of fabrication, fiber architecture, considered damage threat, and targeted residual strength. A sampling of materials and their respective densities are shown in Table 2.

Table 2 - Densities and moduli for select materials

NOTE: REFERENCE ONLY, ALL COMPOSITE VALUES ARE APPROXIMATE FOR UNIDIRECTIONAL FIBERS

Material	Density lb/in ³ (g/cc)	Modulus MSI (GPa)	Specific Modulus (10 ⁶ m ² /s ²)
Carbon/Epoxy Composite (~60% FV)	0.057 (1.6)	20.6 (142)	89
Carbon/PAEK Composite (~60% FV)	0.057 (1.6)	19.1 (132)	83
Fiberglass Composite (~45% FV)	0.065 (1.8)	5.8 (40)	22
Aluminum Alloys	0.101 (2.7)	10.6 (73)	27
Titanium	0.160 (4.4)	16.0 (110)	26
Steel	0.283 (7.8)	29 (200)	25

5.1.1.2 Corrosion Resistance

Composite materials provide exceptional corrosion resistance. Composites do not rust or corrode, and properly selected reinforcement and resin systems will maintain resistance to typical aircraft fluid exposure for their expected service life. However, the galvanic compatibilities of materials are important to assess.

5.1.2 Joining Methods

Composites are capable of being bonded, welded (thermoplastic only), and joined using typical fasteners.

Where bonding is used, it is typical to ensure compatibility between the resin system and adhesive. As with any type of bonding, the proper surface preparation technique needs to be identified. Manual abrasion, grit blasting, and plasma etching are potential surface preparation methods. A production representative bonding process is normally qualified as part of the part design process.

NOTE: Bonding associated with applications of any safety criticality requires particular attention because such technologies are very dependent upon strict process control, and industry-wide inspection methods have not been developed which may detect some bonding damage modes, e.g., "weak bonds." Refer to CMH-17 and AC 20-107B/AMC 20-29 para. 6.

Thermoplastic composites are capable of being welded due to their ability to be remelted and cooled. Thermoplastic welding is being considered for large scale structures to reduce or eliminate traditional fastening methods. Welding may have applicability to landing gear primary structure dependent upon the application, joint configuration, and other requirements.

Given their relatively low bearing strength and their susceptibility to delamination, certain design and drilling precautions are taken when joining composite parts by means of fasteners. Note that these precautions may have a negative impact on cost and weight reduction considered when selecting the structural design.

5.1.3 Paint/Primer

Paints and/or primers may be used with composite components for aesthetic reasons and less commonly as a means of galvanic isolation. Major original equipment manufacturers (OEMs) generally have specifications in place to control primers, paints, and associated surface preparations. Adhesion of primer or paint is key to the durability and longevity of the coating. Other coating techniques may be available but are qualified on an application-specific basis.

5.1.4 Durability, Maintenance, and Repair

Composite components can provide exceptional durability when the appropriate part design and material selection is used on a particular application. Design elements, such as metallic bushings for wear or repeated assembly/disassembly areas, increase component durability and decrease associated maintenance costs. The repair of primary landing gear components made of composite materials is typically laborious and time intensive. Repair processes of primary structures need to be considered at time of structure design.