

AVIATION PARTNERS INC.

GENERAL CONSIDERATIONS FOR COMPOSITE DESIGN



- **Lightning Strike**
- **Corrosion Prevention**
- **Allowables Dilemma**
- **Tooling Expense**

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API's main business involves the design, fabrication, and installation of Winglet modification kits.

We have over 5000 Shipsets of Winglets installed on a variety of commercial and business aircraft.

We have nine US STC's (covering 24 different models) with subsequent validation from EASA, Transport Canada, Mexico, & Brazil amongst others.

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Gulfstream II



Hawker 800A/B



Hawker 800XP



Falcon 2000



Falcon 2000EX/DX



Falcon 2000LX



Hawker 750



Falcon 900/B/C



Falcon 900EX/DX



Falcon 900LX



Falcon 50



Falcon 50EX



Boeing BBJ



Boeing 737-800



Boeing 737-700



Boeing BBJ2



Boeing 737-300



Boeing 757-200



Boeing 737-700C



Boeing 737-500



Boeing 737-900/ER



Boeing BBJ3



Boeing 767-300ER/F



Boeing 757-300



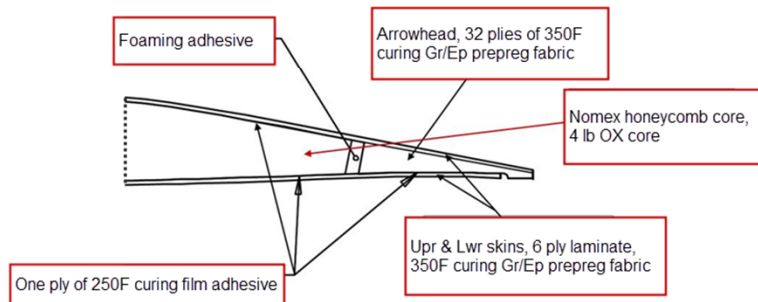
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Hawker 800 & Falcon Winglet General Construction

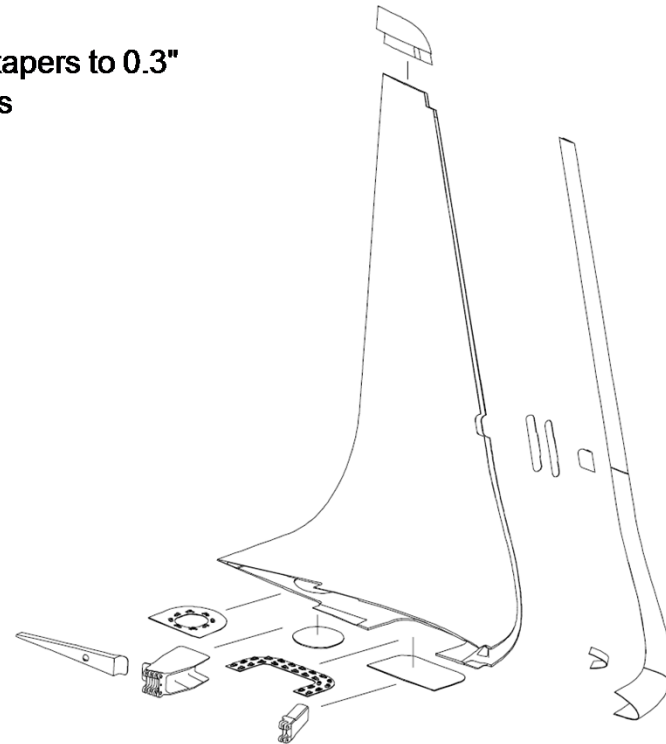


Hawker 800:

- Gr/Ep skins, thickness ranges from 0.25" at the root to approximately 0.04" near the tip
- Full depth nomex core, no spars or ribs
- Aluminum leading edge, removable, attached with bolts and nut-plates, grounded to the airframe
- Aluminum tip cap, electrically bonded to the leading edge
- Solid Gr/Ep trailing edge, min thickness 0.1" along the TE, tapers to 0.3" along the fwd edge, approximately 1" wide, bonded to skins
- CRES attach fittings at F.S. and R.S.
- Aluminum TE close out rib



Trailing Edge Detail



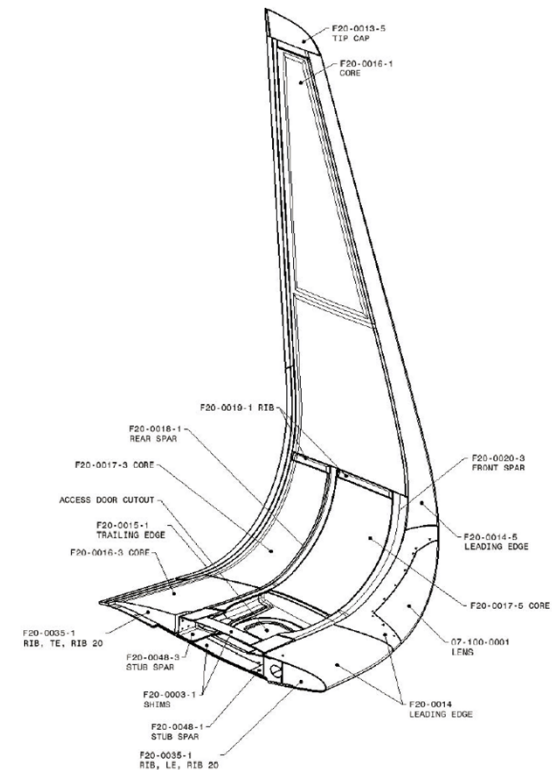
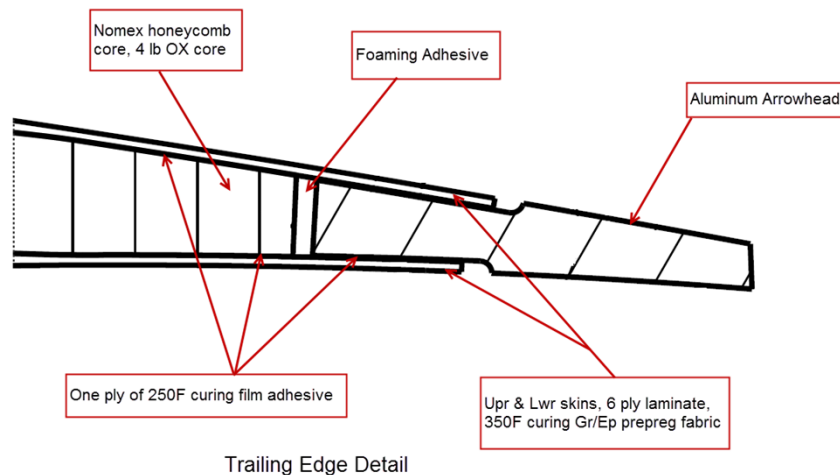
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Hawker 800 & Falcon Winglet General Construction



Falcon (50, 2000, & 900)

- Gr/Ep skins, thickness ranges from 0.25" at the root to approximately 0.04" near the tip
- Gr/Ep Spars & Ribs bonded to skins and mechanically fastened to attach fittings
- Aluminum leading edge, removable, attached with bolts and nut-plates, grounded to the airframe
- Aluminum tip cap, electrically bonded to the leading edge
- Aluminum trailing edge, electrically bonded to tip cap and the airframe
- Aluminum attach fittings at F.S., R.S., and continuous joint along the skins
- Full depth nomex core (upper blade section only)



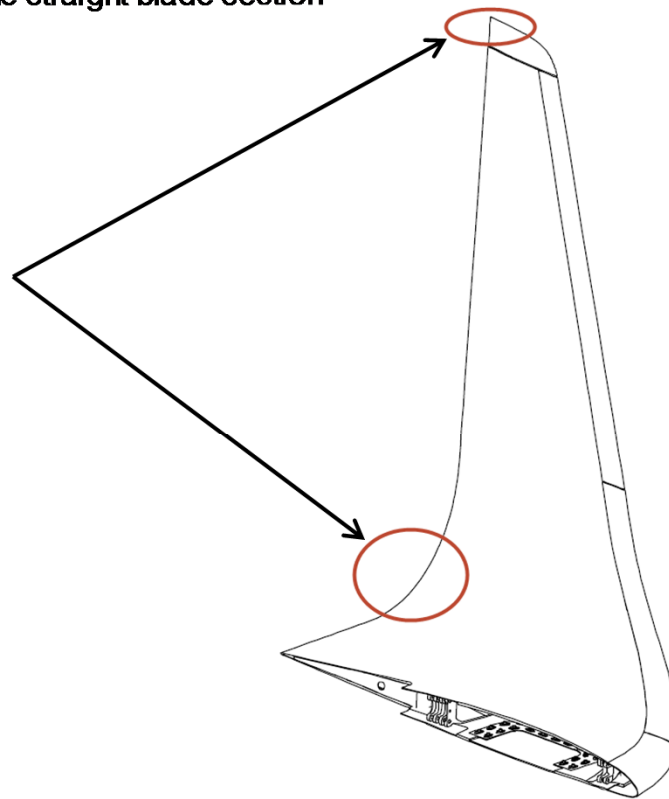
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Hawker 800 & Falcon Lightning Strike

The Winglets typically show two major areas of lightning attachment:

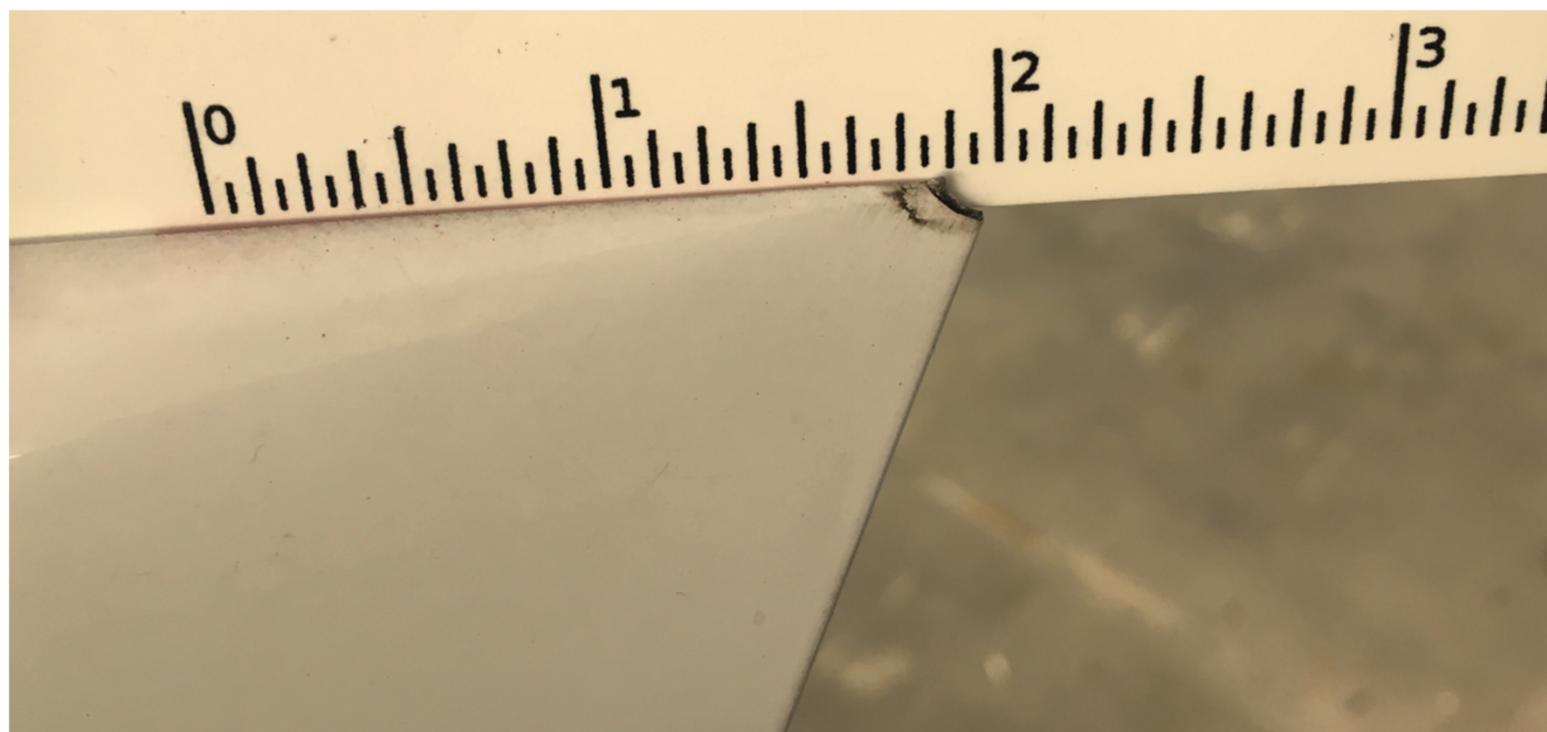
- Upper trailing edge of the tip cap
- Winglet trailing edge in the radius area below the straight blade section

Lightning Strike Attachment Areas



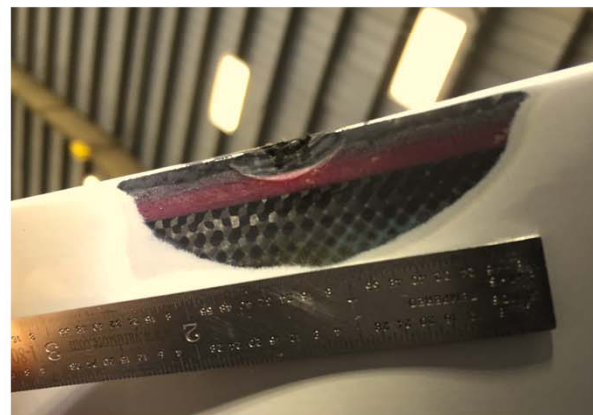
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HAWKER 800 WINGLET: Lightning Strike Damage



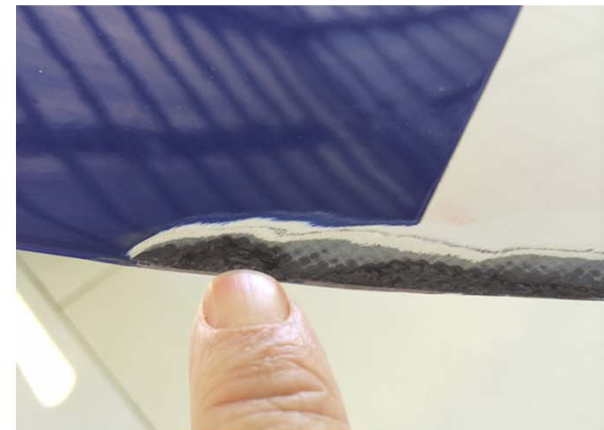
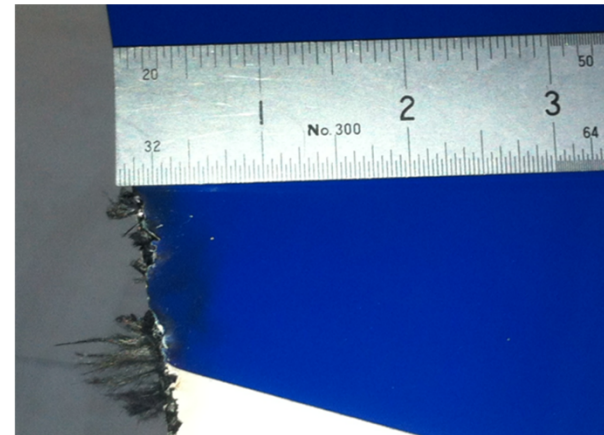
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HAWKER 800 WINGLET: Lightning Strike Damage



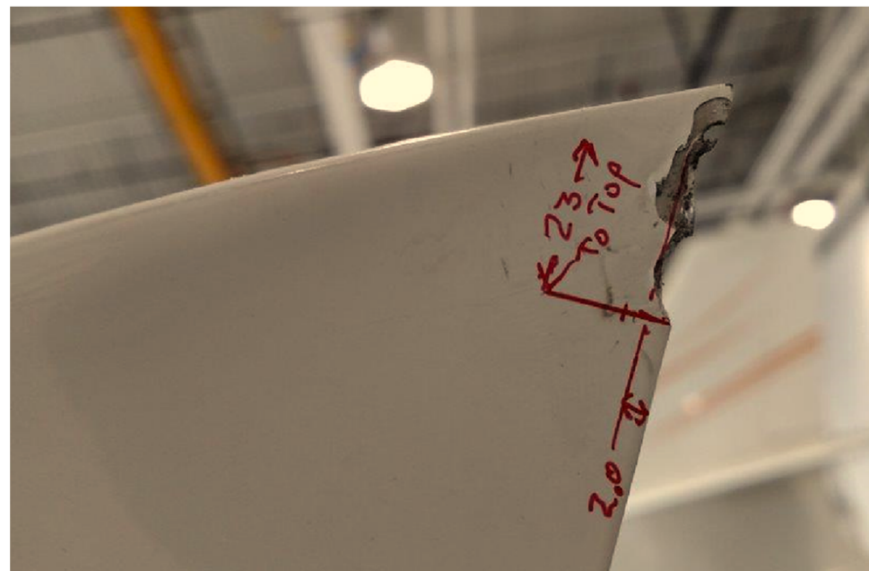
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Hawker 800 Winglet: Lightning Strike Damage



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FALCON WINGLET: Lightning Strike Damage



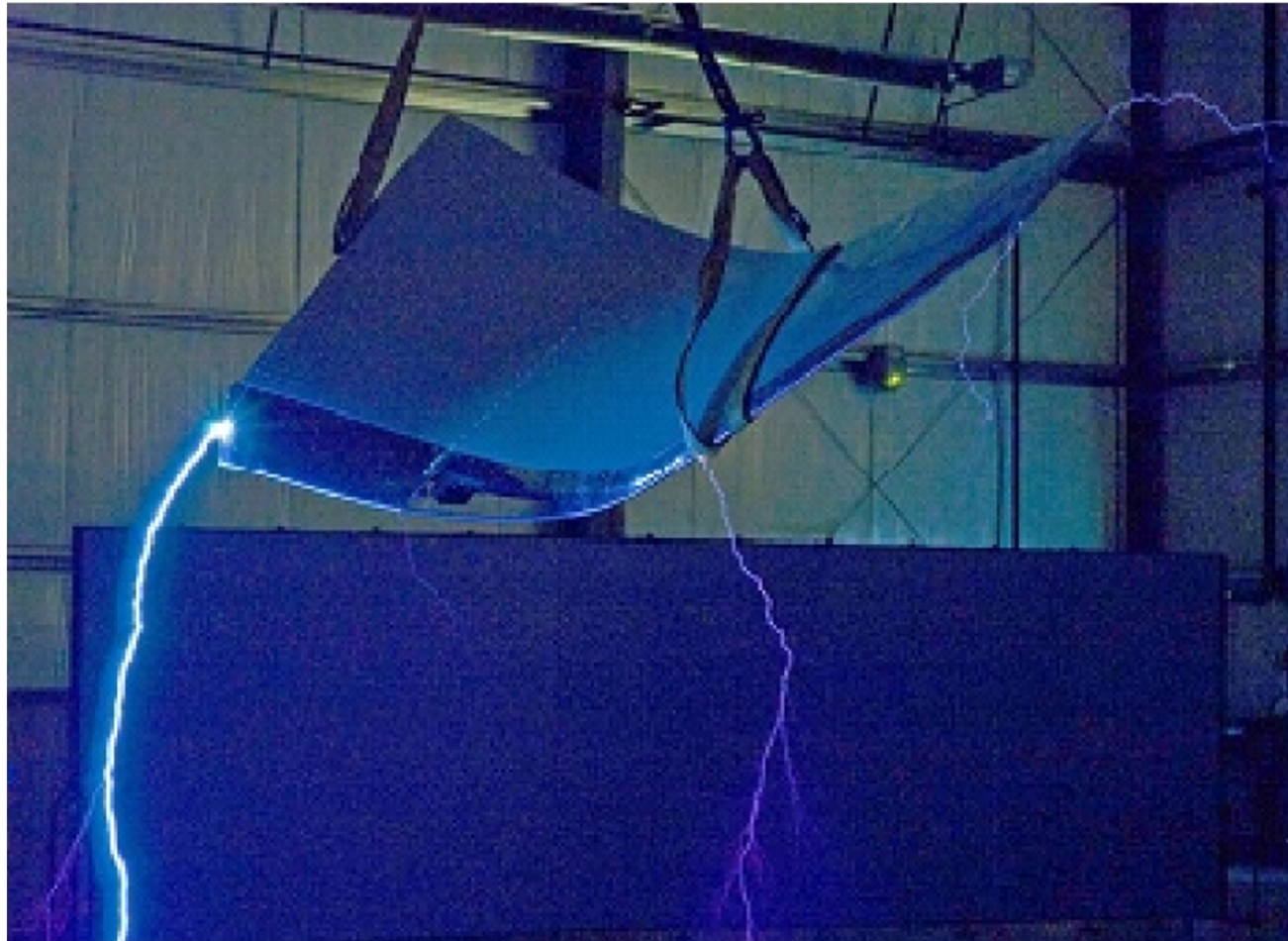
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FALCON WINGLET: Lightning Test



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FALCON WINGLET: Lightning Test



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Lightning Strike Protection



The Winglets exhibit two main sites for possible lightning damage:

- Tip cap trailing edge
- Winglet trailing edge in the radius transition area

Picture framing the composite structure with metallic components has proven to be effective protection.

- Metallic leading edge, tip cap, & trailing edge
- All of the metallic components are electrically bonded to adjacent metal structure
- At the winglet root the metal components are electrically bonded to the airframe

Use of heavy gage composite elements is successful in minimizing any lightning damage

- Minor repairs will be necessary, but the damage is non-structural in nature

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Corrosion Prevention



Corrosion of metals are of particular concern when in contact with Gr/Ep composites. There is a potential for corrosion due to dissimilar metals contact.

The following design guidelines are applied to all graphite composites that are in contact with metal structure.

- A fiberglass barrier ply is bonded to the faying surface of the graphite composite.
The fiberglass barrier covers the entire faying surface and extends at least 4 inches beyond the edge of the metal part in any direction.
No splices are allowed in the barrier ply.
- If bonded, a non-conductive adhesive is used.
- If mechanically attached without bonding, a non conductive fay surface sealant is used.
- All fasteners are installed with sealant.
- All fasteners are corrosion resistant (A286, Titanium).
- All fasteners are aluminum coated.

This design philosophy has proven to be effective. Thus far there have been no service reports related to dissimilar metals corrosion.

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Allowables Delimma



Most material systems do not have a readily available comprehensive set of allowables for use on type certificated hardware.

Those companies that spend the resources necessary to develop a comprehensive allowables database are unwilling to share the data.

AGATE was an attempt to remedy this situation. However, the data that is available is very incomplete.

Typically available databases only contain laminae data with limited laminate allowables.

The allowables used for design must account for degradation due to temperature and moisture affects, and must include the affect of impact damage.

Very limited data is available for laminate strength after impact. Open hole allowables are not well documented.

Bearing strength is sometimes presented, but only for a limited number of layups.

Bearing and Bypass interaction is not well addressed. Where data is available it typically only covers a limited range of bearing/bypass ratios, and only for a limited number of layups.

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Allowables Delimma



A significant number of design parameters are not addressed by most available datasets:

Diameter correction factors: for many laminates large diameter holes and fasteners show reduced strength compared to the normal range of fastener diameters (5/32" to about 3/8")

Composites should be designed using and edge distance of 2.5 e/d. Shorter edge distances will have much reduced bearing (and bypass) strength.

The presence of countersinks will reduce observed bearing and bypass strengths.

The presence of butt splices will reduce observed bearing and bypass strengths.

Much of the bearing data is obtained using double shear testing. Unstabilized single shear joints will show reduced bearing strengths.

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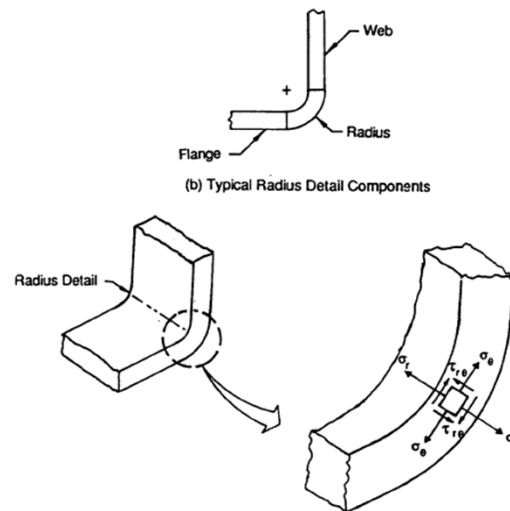
Allowables Delimma

A significant number of design parameters are not addressed by most available datasets:

Standard design details are not addressed by many of the publically available databases.

For example, nearly every rib or spar has radius details where the web intersects the flange. These details experience significant interlaminar tension and interlaminar shear stress.

But analysis and allowables for these very common details are not really addressed in most databases.



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Allowables Delimma



Need to plan, budget, and schedule your projects to allow for significant allowables and sub-component testing.

Existing databases can not be relied on to provide all of the design data that will be required.

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Tooling Effort



Need to be prepared for higher than usual non recurring costs and initial lead time for tooling.

Example:

Falcon Winglet has 16 major components per side, 32 per shipset.

This generated 170 distinct tools, including:

- 20 Bond Assy Jigs
- 8 Drill Fixtures
- 10 Router Fixtures
- 6 Trim Fixtures
- 38 Core Tools
- 8 Holding Fixtures
- 10 Mandrels
- 2 Milling Fixtures
- 38 NC Programs to control ply cutting

Design changes that impact tooling are strongly discouraged.

- Greatly restricts flexibility for sustaining engineering efforts.
- Do not make the initial design with zero margins, no room for growth, no inexpensive recovery for load increases.

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Tooling Effort



Tool Number	Tool Description	Tool Code	Tool Number	Tool Description	Tool Code	Tool Number	Tool Description	Tool Code
Master Gage						NCP's (Graphite Plys, Tape - Numerical Control Programs, Gerber Ply Cutter)		
MA81701201F2MB101WL		MA	HRX's (Hand Router Fixtures) Spars and Ribs			F20-0010-1	Upper Skin, L/H	2NCP
MA81701201F2MB102WL		MA	F20-0018-1	Spar 1, Leading Edge, L/H	HRX	F20-0010-2	Upper Skin, R/H	2NCP
BAJ's (Bonded Assembly Jigs)			F20-0018-2	Spar 1, Leading Edge, R/H	HRX	F20-0011-1	Lower Skin, L/H	2NCP
F20-0010-1	Upper Skin, L/H	BAJ1	F20-0018-3	Spar 2, Trailing Edge, L/H	HRX	F20-0011-2	Lower Skin, R/H	2NCP
F20-0010-2	Upper Skin, R/H	BAJ1	F20-0018-4	Spar 2, Trailing Edge, R/H	HRX	F20-0012-1	Access Door, L/H	2NCP
F20-0011-1	Lower Skin, L/H	BAJ1	F20-0019-1	Rib 1, Center, L/H	HRX	F20-0012-2	Access Door, R/H	2NCP
F20-0011-2	Lower Skin, R/H	BAJ1	F20-0019-2	Rib 1, Center, R/H	HRX	NCP's (Fiberglass Plys, Woven - Numerical Control Programs, Gerber Ply Cutter)		
F20-0012-1/-2	Access Door, L/H & R/H	BAJ1	F20-0019-3	Rib 2, MID, L/H	HRX	F20-0010-1	Upper Skin, L/H	3NCP
F20-0018-1	Spar 1, Leading Edge, L/H	BAJ1	F20-0019-4	Rib 2, MID, R/H	HRX	F20-0010-2	Upper Skin, R/H	3NCP
F20-0018-2	Spar 1, Leading Edge, R/H	BAJ1	F20-0019-5	Rib 3, AFT, L/H	HRX	F20-0011-1	Lower Skin, L/H	3NCP
F20-0018-3	Spar 2, Trailing Edge, L/H	BAJ1	F20-0019-6	Rib 3, AFT, R/H	HRX	F20-0011-2	Lower Skin, R/H	3NCP
F20-0018-4	Spar 2, Trailing Edge, R/H	BAJ1	Various	Steel Guides	n/a	F20-0012-1	Access Door, L/H	3NCP
F20-0019-3	Rib 2, MID, L/H	BAJ1	NCP's (Graphite Plys, Woven - Numerical Control Programs, Gerber Ply Cutter)			F20-0012-2	Access Door, R/H	3NCP
F20-0019-4	Rib 2, MID, R/H	BAJ1	F20-0010-1	Upper Skin, L/H	NCP	F20-0018-1	Spar 1, Leading Edge, L/H	3NCP
F20-0019-5	Rib 3, AFT, L/H	BAJ1	F20-0010-2	Upper Skin, R/H	NCP	F20-0018-2	Spar 1, Leading Edge, R/H	3NCP
F20-0019-6	Rib 3, AFT, R/H	BAJ1	F20-0011-3	Lower Skin, L/H	NCP	F20-0018-3	Spar 2, Trailing Edge, L/H	3NCP
F20-0019-7	Rib 1, Center, L/H	BAJ1	F20-0011-4	Lower Skin, R/H	NCP	F20-0018-4	Spar 2, Trailing Edge, R/H	3NCP
F20-0019-8	Rib 1, Center, R/H	BAJ1	F20-0012-1	Access Door, L/H	NCP	NCP's (Numerical Control Programs, Virtex Projector)		
F20-0020-1	Bonded Assembly, L/H	BAJ1	F20-0012-2	Access Door, R/H	NCP	F20-0010-1	Upper Skin, L/H	NCPL
F20-0020-2	Bonded Assembly, R/H	BAJ1	F20-0018-1	Spar 1, Leading Edge, L/H	NCP	F20-0010-2	Upper Skin, R/H	NCPL
F20-0023-1	Gusset Angle L/H	BAJ1	F20-0018-2	Spar 1, Leading Edge, R/H	NCP	F20-0011-1	Lower Skin, L/H	NCPL
F20-0023-2	Gusset Angle R/H	BAJ1	F20-0018-3	Spar 2, Trailing Edge, L/H	NCP	F20-0011-2	Lower Skin, R/H	NCPL
DRX's (Drill Fixtures)			F20-0018-4	Spar 2, Trailing Edge, R/H	NCP	NCP's (Numerical Control Programs, 5 Axis Router)		
F20-0001-1	Winglet Drill Fixture	DJ	F20-0019-1	Rib 1, Center, L/H	NCP	F20-0020-1	Bonded Assembly, L/H	NCP
F20-0001-2	Winglet Drill Fixture	DJ	F20-0019-2	Rib 1, Center, R/H	NCP	F20-0020-2	Bonded Assembly, R/H	NCP
F20-0012-1	Access Door Drill Tool, LH (DX)	DF1	F20-0019-3	Rib 2, MID, L/H	NCP	Mill Fixtures		
F20-0012-2	Access Door Drill Tool, RH (DX)	DF1	F20-0019-4	Rib 2, MID, R/H	NCP	F20-0020-1	Bonded Assembly Milling Fixture, MF	
F20-0019-1/-2/-5	RIB 1, INB'D & RIB 2, INB'D	DRX1	F20-0019-5	Rib 3, AFT, L/H	NCP	F20-0020-2	Bonded Assembly Milling Fixture, MF	
F20-0019-3/-4/-6	RIB 3, OUTB'D & RIB 4, OUTB'D	DRX1	F20-0019-6	Rib 3, AFT, R/H	NCP			
F20-0055-1	Assy) PART 1 OF 2	DRX1	F20-0023-1	Angle Support, L/H	NCP			
F20-0055-5	Assy) PART 2 OF 2	DRX1	F20-0023-2	Angle Support, R/H	NCP			

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Tooling Effort



Tool Number	Tool Description	Tool Code	Tool Number	Tool Description	Tool Code	Tool Number	Tool Description	Tool Code
Trim Fixtures			Locating Fixtures LX's			Core Tooling NRC		
F20-0012-1	Access Door, L/H	DX	F20-0002-1	IML Holding Fixture - L/H Center C HF1		F20-0016-1	SIDE 2 - LEFT	MILF
F20-0012-2	Access Door, R/H	DX	F20-0002-2	IML Holding Fixture - R/H Center C HF1		F20-0016-2	SIDE 1 - RIGHT	MILF
F20-0020-1	Bonded Assy, Trailing Edge, L/H	TDX	F20-0002-1	IML Holding Fixture - L/H Center C HF2		F20-0016-2	SIDE 2 - RIGHT	MILF
F20-0020-2	Bonded Assy, Trailing Edge, R/H	TDX	F20-0002-2	IML Holding Fixture - R/H Center C HF2		F20-0016-2	SIDE 2 - RIGHT (REWORK)	MILF
F20-0020-3	Drill Fixture for TDX Tool	DF	F20-0002-1	IML Holding Fixture - L/H Center C BAJ1		F20-0016-3	SIDE 2 - LEFT (FEMALE)	MILF
F20-0020-4	Drill Fixture for TDX Tool	DF	F20-0002-2	IML Holding Fixture - R/H Center C BAJ1		F20-0016-3	SIDE 2 - LEFT (FEMALE) - REWORK	MILF
			F20-0002-3	F20-0014-1 & F20-0035-3 Locatin LX		F20-0016-3	SIDE 2 - LEFT (FEMALE) - REWORK	MILF
			F20-0002-4	F20-0014-2 & F20-0035-4 Locatin LX		F20-0016-3/-4	SIDE 1 - RISER	MILF
						F20-0016-3/-4	N/A	PLTF
Handling Carts			Rubber Mandrel & Intensifier (Shop Aid)			F20-0016-3/-4		
F200010/11	Handling Carts - "C" scan (skins)	HC	F20-0018-1	Spar 1, Leading Edge, L/H (Intens FAB		F20-0016-4	SIDE 1 -3/-4 (FLAT)	MILF
F20-0010-1	Handling Carts -BAJ Mold Cart	BAJ01	F20-0018-2	Spar 1, Leading Edge, R/H (Intens FAB		F20-0016-4	SIDE 2 - RIGHT (FEMALE)	MILF
F20-0010-2	Handling Carts -BAJ Mold Cart	BAJ01	F20-0018-3	Spar 2, Trailing Edge, L/H (Intensi FAB		F20-0016-4	SIDE 2 - RIGHT (FEMALE) - REWORK	MILF
F20-0020-1	Handling Carts -BAJ Mold Cart	BAJ01	F20-0018-4	Spar 2, Trailing Edge, R/H (Intens FAB		F20-0017-1	SIDE 2 - RIGHT (FEMALE) - REWORK	MILF
F20-0020-2	Handling Carts -BAJ Mold Cart	BAJ01	F20-0018-1	Rib 2, MID, L/H (Rubber Mandrel FAB		F20-0017-1	SIDE 1 - LEFT (FEMALE)	MILF
n/a	Winglet Detail Carts	HC	F20-0019-1	Rib 2, MID, R/H (Rubber Mandrel FAB		F20-0017-1	SIDE 1 - LEFT (FEMALE) - REWORK	MILF
n/a	Complete Winglet Kits Cart	HC	F20-0019-2	Rib 3, MID, L/H (Rubber Mandrel FAB		F20-0017-1	SIDE 1 - LEFT (FEMALE) - REWORK	MILF
			F20-0019-3	Rib 3, MID, R/H (Rubber Mandrel FAB		F20-0017-2	SIDE 1 - RIGHT (FEMALE)	MILF
Holding Fixtures HX			F20-0019-4	Rib 3, MID, R/H (Rubber Mandrel FAB		F20-0017-2	SIDE 1 - RIGHT (FEMALE) - REWORK	MILF
F20-0010-1	Upper Skin, L/H	DES	F20-0019-5	Rib 3, AFT, L/H (Rubber Mandrel) FAB		F20-0017-2	STABILIZATION FIXTURE	HTRF
F20-0010-2	Upper Skin, R/H	FAB	F20-0019-6	Rib 3, AFT, R/H (Rubber Mandrel) FAB		F20-0017-2	SIDE 1 - RIGHT (FEMALE) - REWORK	MILF
						F20-0017-2	SIDE 1 - RIGHT (FEMALE) - REWORK	MILF
Leading Edge Tooling NRC			Detail Part Related NRC			F20-0017-3		
F20-0014-1	Inboard Leading Edge, L/H	FD	Trailing Edge			F20-0017-3		
F20-0014-1	Vacuum Holding Fixture - Inboard	HF	F20-0015-1/-2	Three Parts to Milling Fixtures	MF	F20-0017-3	SIDE 1 - LEFT (FEMALE)	MILF
F20-0014-1/-2	Blade Check Fixture - Trim Only	CF	F20-0015-3/-4	One Part to Milling Fixture	MF	F20-0017-3	SIDE 2 - LEFT (MALE) - REWORK	MILF
F20-0014-2	Inboard Leading Edge, R/H	FD	F20-0015-5/-6	Two Parts to Milling Fixtures	MF	F20-0017-4	SIDE 2 - LEFT (MALE) - REWORK	MILF
F20-0014-2	Vacuum Holding Fixture - Inboard	HF				F20-0017-4	SIDE 1 - RIGHT (FEMALE)	MILF
F20-0014-3	Mid Leading Edge, L/H	FD				F20-0017-4	SIDE 1 - RIGHT (FEMALE)	MILF
F20-0014-3	Vacuum Holding Fixture - Mid Lead	HF				F20-0017-4	SIDE 2 - RIGHT (MALE)	MILF
F20-0014-3/-4	Blade Check Fixture - Trim Only	CF				F20-0017-4	STABILIZATION FIXTURE	HTRF
F20-0014-4	Mid Leading Edge, R/H	FD				F20-0017-4	SIDE 1 - RIGHT (FEMALE) - REWORK	MILF
F20-0014-4	Vacuum Holding Fixture - Mid Lead	HF				F20-0017-4	SIDE 2 - RIGHT (MALE) - REWORK	MILF
F20-0014-5	Outboard Leading Edge, L/H	FD				F20-0017-5	SIDE 1 - LEFT (PART NUMBER WAS -	MILF
F20-0014-5	Vacuum Holding Fixture - Outboard	HF				F20-0017-5	STABILIZATION FIXTURE (WAS -1 NC	HTRF
F20-0014-5/-6	Blade Check Fixture - Trim Only	CF				F20-0017-5	SIDE 2 - LEFT (REMAKE DUE TO DAM	MILF
F20-0014-6	Outboard Leading Edge, R/H	FD				F20-0017-6	SIDE 1 - RIGHT (PART NUMBER WAS	MILF
F20-0014-6	Vacuum Holding Fixture - Outboard	HF				F20-0017-6	STABILIZATION FIXTURE (WAS -1 NC	HTRF
F20-0014-7	Leading Edge - Splice, L/H	FD				F20-0017-6	SIDE 2 - RIGHT (REMAKE DUE TO DA	MILF
F20-0014-8	Leading Edge - Splice, R/H	FD				F20-0017-ALL	RISER	MILF