FAA/EASA Composite Transport Workshop on Fatigue, Damage Tolerance, Maintenance and Crashworthiness

European Aviation Safety Agency

FEDERAL AVIATION ADMINISTRATION

17th to 19th of May 2011, Atlanta

LEF factors and composite/metal fatigue

LARGE SCALE COMPOSITE FATIGUE TEST PROTOCOL

Presented by
Fualdes Chantal : A350XWB-Composite Structure Certification
Ratier Louis : A350XWB-Composite Fatigue

AIRBUS

Content

Hybrid Fatigue full scale Cells ?

- Needs of hybrid cells
- Metallic and Composite test scenarios

LEF definition

- Initial approach: Northrop
- Other analyses
- LEF trends versus scatter analysis

Perspectives

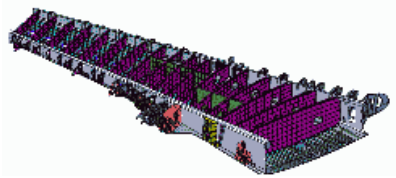
Hybrid Fatigue Full scale Cells ?

➔ Needs of Hybrid fatigue Cell:

- More and more hybrid structures: A320 ~10%, A380 ~30% A350 ~50%

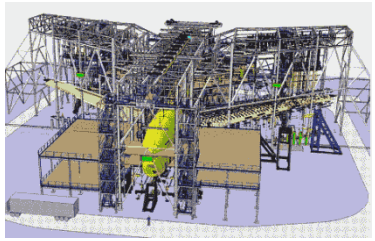
  Even among component parts, mixed material:

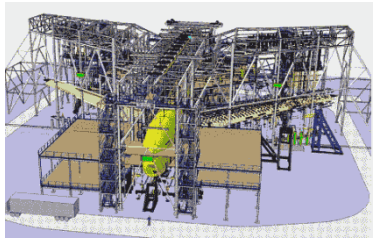
  How to test hybrid junctions



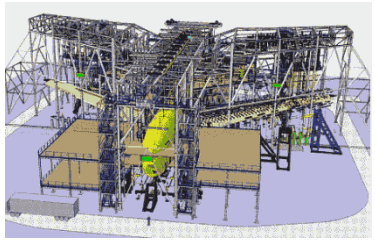
- Cost & Time saving:

2 Fatigue Cells (Metal +CFRP)





1 Hybrid Fatigue Cell

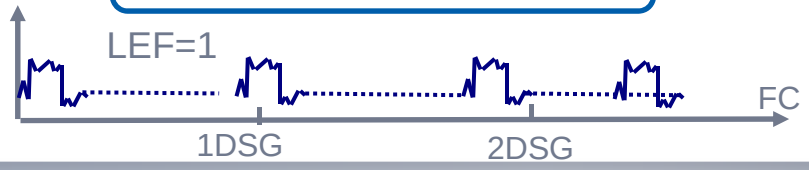


Hybrid Fatigue Full scale Cells ?

Current scenarios:

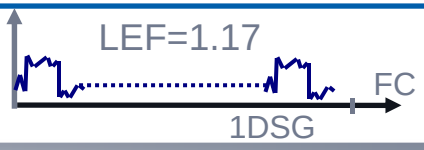
Metal test scenario

- Fatigue sensitive areas: all stress concentration areas
- Fatigue mainly driven by local tension loading R=0.1
- Scatter covered by Test Life factor : 2 …3



Composite test scenario

- Fatigue sensitive features:
  Feature with out-of-plane stresses
  Shear and Tensile inter lamina strength
- Compression: Mainly driven by compression and alternative loading R=-1
- Scatter covered by LEF Load Enhancement Factor: 1.17*
  *from Northrop approach

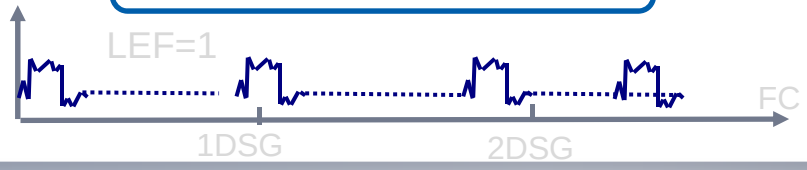


Hybrid Fatigue Full scale Cells ?

Current scenarios:

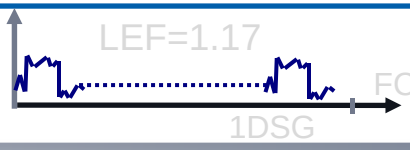
Metal test scenario

- Fatigue sensitive areas: all stress concentration areas
- Fatigue mainly driven by local tension loading R=0.1
- Scatter covered by Test Life factor : 2 …3



Composite test scenario

- Fatigue sensitive features:
  Feature with out-of-plane stresses
  Shear and Tensile inter lamina strength
- Compression: Mainly driven by compression and alternative loading R=-1
- Scatter covered by LEF Load Enhancement Factor: 1.17*
  *from Northrop approach



Composite Test pyramid

Tests / Analyses / Specifications

Analyses

- Fatigue insensitive threshold
- Stress analysis
- Residual strength after repetitive loading
- Onset of Damage growth

Specifications:

AA requirements/Design directives

Material qualification (CS:25.603&AC20.107B,§8b)

- **Suitability and durability of materials after repeated loading**

Durability (economic)

- Damage free life
- No growth of BVID and acceptable manufacturing defects

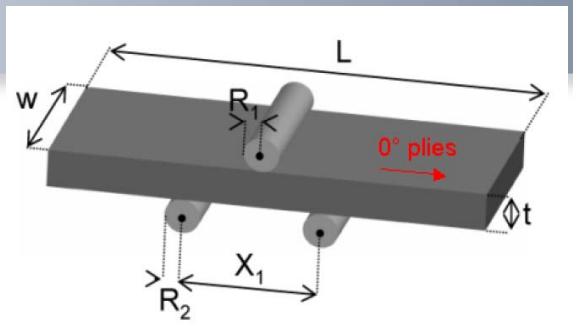
Damage tolerance

(CS 25.571&AC20.107B $8(a)2)

- No detrimental growth of V.I.D
- No detrimental growth of undetectable impact damages (if any, due to DT impacts up to 10^{-9} energy threshold)

Fatigue method for composite:

Wöhler curve



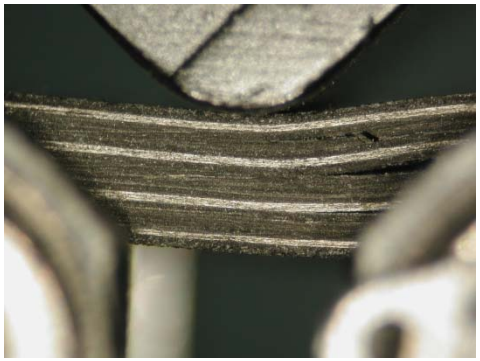
- Fatigue sensitive feature :

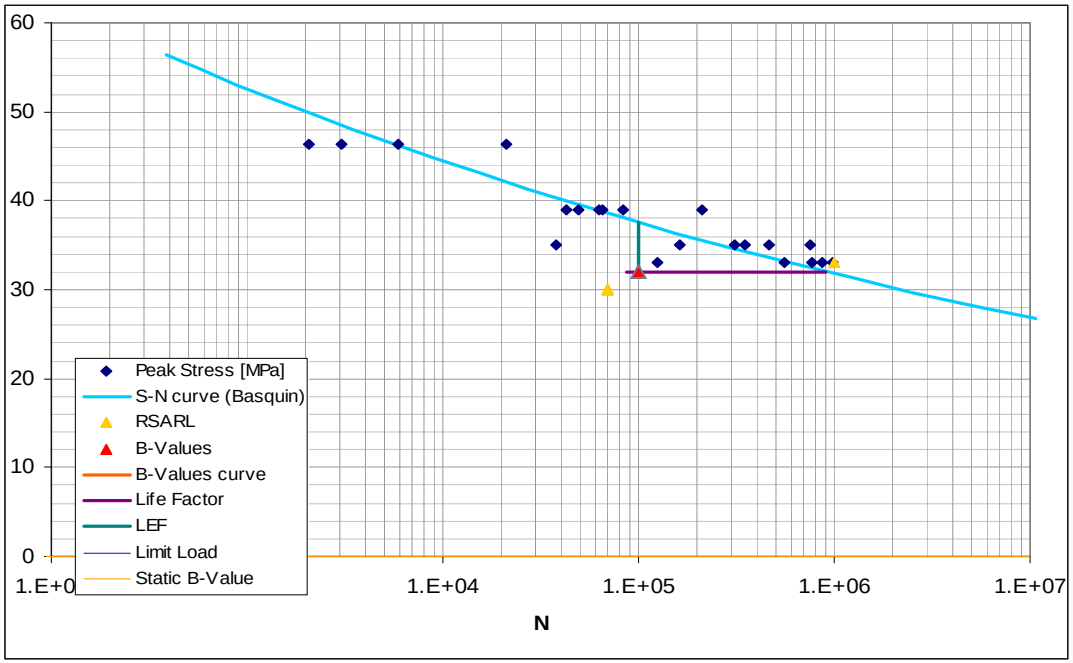
•Example : Inter Laminar Shear Stress Test

•t=4mm, W=15, L=40mm X=20

% static failure strength

$N=C(|\sigma max|)^{-m}$



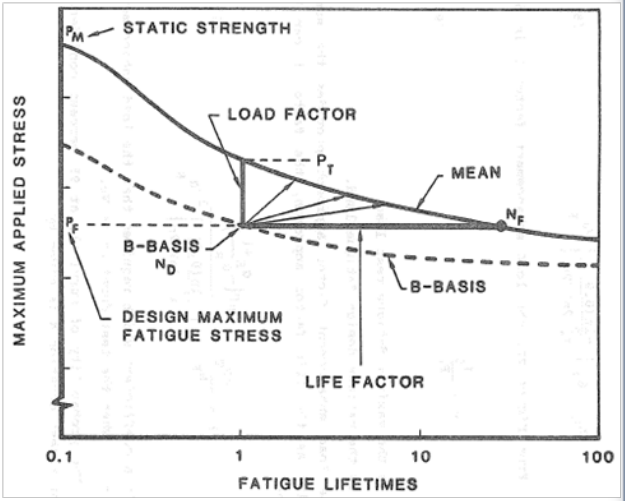


Failure/Residual strength/B values

➔ **Fatigue features sensitivity drive the design principle**

LEF definition

Load Enhancement Factor has been introduced on fatigue composite full scale test as a response to the higher scatter observed on fatigue composite tests



Composite standard approach:

1986-Northrop's report proposed a 2 parameters Weibull law analysis.

Resulting from a large number of coupon tests,

N	1	1.5	3	13.3
LEF	1.177	1.148	1.10	1

$$LEF = \left(\frac{N_F}{N}\right)^{\frac{\alpha_L}{\alpha_R}}$$

$$N_F = \frac{\Gamma\left(\frac{\alpha_L+1}{\alpha_L}\right)}{\left[\frac{-\ln(p)}{\chi^2_\gamma(2n)/2n}\right]^{\frac{1}{\alpha_L}}}$$

N_F is the resulting life factor for LEF=1
α_R Weibull shape parameter for the scatter on residual strength properties
α_L Weibull shape parameter for the scatter on fatigue life properties
p Survival probability (90% for the B-value definition)
g Confidence (95%)
N Coefficient applied on the life (N = Life Factor when LEF = 1)
n Number of test articles (usually one for a full-scale test)

Remarks : Test campaign with all failure mode (not focused on sizing criteria)

LEF definition (con't)

Other analyses:

$$N_F = \frac{\Gamma\left(\frac{\alpha_L+1}{\alpha_L}\right)}{\left[\frac{-\ln(p)}{\chi^2_\gamma(2n)/2n}\right]^{\frac{1}{\alpha_L}}} \qquad LEF = \left(\frac{N_F}{N}\right)^{\frac{\alpha_L}{\alpha_R}}$$

	Imputs		Outputs			
	Alpha R	Alpha L	LEF (1DSG)	LEF (1.5DSG)	LEF (3DSG)	Nf (LEF=1)
Northrop 1986	**20,00**	**1,25**	**1,177**	**1,15**	**1,10**	**13,56**
EADS ATR 1989			1,10			5,13
EADS CASA 2001	19,86	2,74	1,16	1,10	1,00	3,02
NIAR 2008 AS4/E7K8	24,23	1,74	1,14	1,11	1,05	6,09
NIAR 2008 T700	34,58	4,06	1,09	1,04	0,96	2,07
Airbus 2011 FatSensF	24,20	2,31	1,14	1,09	1,02	3,78

LEF Trends versus (α_R,α_L)

α_R ↗ => LEF(1DSG) ↘

⇒ but static scatter ↘

α_L ↗ => LEF(3DSG) ↘

	Alpha R	Alpha L	LEF (1DSG)	LEF (1.5DSG)	LEF (3DSG)	Nf (LEF=1)	Coef Variance
	10	1,25	1,385	1,32	1,21	13,56	12,03
Northrop 1986	**20**	**1,25**	**1,177**	**1,15**	**1,10**	**13,56**	**6,20**
	30	1,25	1,115	1,10	1,06	13,56	4,18
	40	1,25	1,085	1,07	1,05	13,56	3,15
	50	1,25	1,067	1,06	1,04	13,56	2,53
Northrop 1986	**20,00**	**1,25**	**1,177**	**1,15**	**1,10**	**13,56**	**6,20**
	20	2	1,168	1,12	1,05	4,73	6,20
	20	4	1,159	1,07	0,93	2,09	6,20

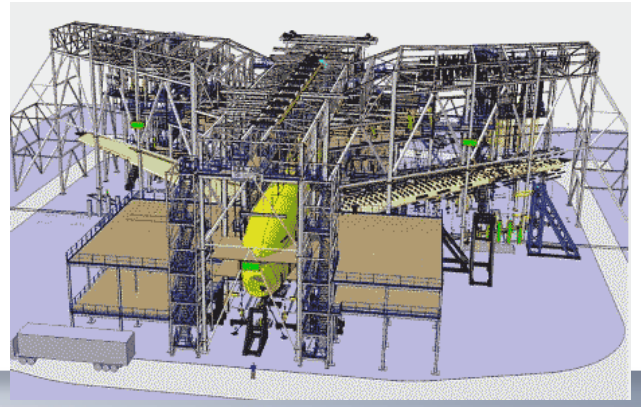
- challenge LEF(1DSG)~1.17 quite ambitious versus Material variance
- opportunity to decrease LEF (2, or 3DSG)

Hybrid Test scenario

Factor to be adjusted

- LEF=1.0 up to 1.05
- Life Factor 2..3 DSG

Adapted scenario



Perspectives

Pre requisite on LEF identification

- Wide materials/process used world wide
- Large population of coupons tests needed
- Set test means

Set the standards of LEF definition

- Pool only fatigue sensitive features
- Define the categories of failure that set up same phenomenon: disbonding; delamination; impacted damage growth, max strength ....
- Justification of Weibull 2 factors analysis

=> Pool one's results upon standards