APPENDIX E

AG22 : Design Methodology for Damage Tolerant Composite Wing Panels

presented by H.H. Ottens

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National Aerospace Laboratory NLR

GARTEUR (SM) AG-22

Design methodology for damage tolerant composite wing panels

1997 - 2001

Participants

Airbus France	**CIRA**
Airbus UK	**DLR**
Airbus Deutschland	**FOI**
Bae Systems	**ONERA**
Saab	**QinetiQ**

Chairman: Jaap Wiggenraad, NLR

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Objectives

1. **Develop analysis methods to predict failure of composite wing panels**
2. **Validate analysis methods by comparing to QinetiQ benchmark test results**
3. **Define recommendations for use with respect to accuracy and efficiency**
4. **Exercise codes to establish design guidelines**

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Statement of Work	*Result*
WP1 Develop methods - leader ONERA	Garteur TP 122-1
WP2 Collect and generate test data - leader QinetiQ	Garteur TP 122-2
WP3 Verify analysis methods - leader FOI	Garteur TP 122-3 and 4
WP4 Recommendations for use - leader CIRA	
WP5 Assessment - leader Saab	Garteur TP 122-5
WP6 Reporting - leader NLR	Garteur TP 122-6

Plan	Realisation
2.5 years	4.5 years
10.3 manyears	13.6 manyears
285 kEcu	395 kEuro

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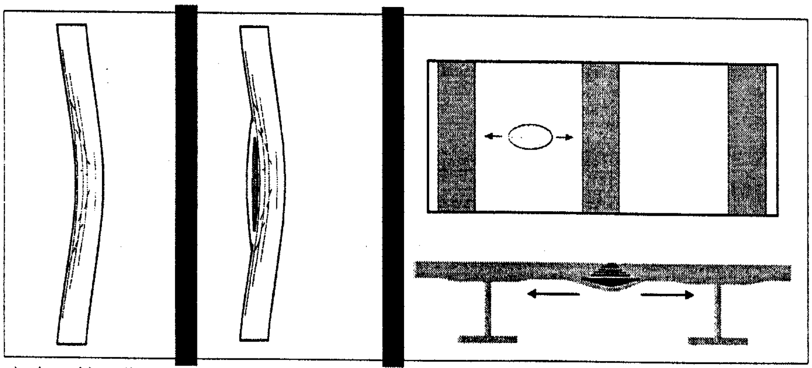
Failure process (QinetiQ) without postbuckling



a) Local bending of the damage region
b) Local buckling of the delaminated plies and the sub-laminate
c) Lateral damage growth

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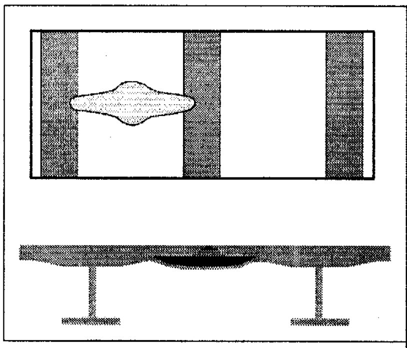
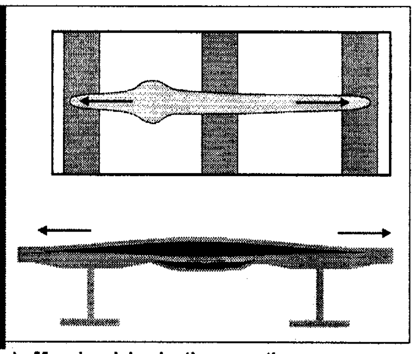
Failure process (QinetiQ)



d) Arrest of the damage growth



e) Massive delamination growth near upper surface

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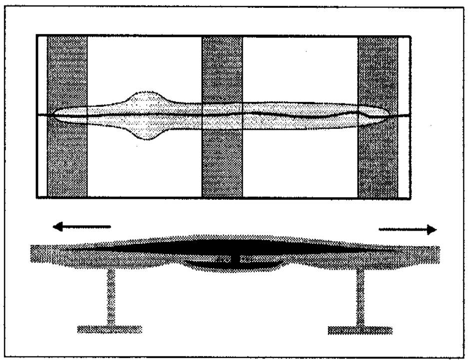
Failure process (QinetiQ)



f) Compression failure of load-bearing plies

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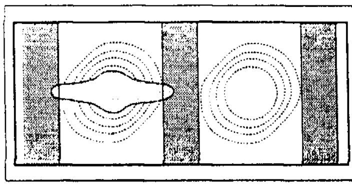
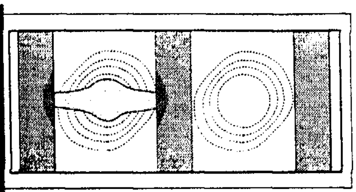
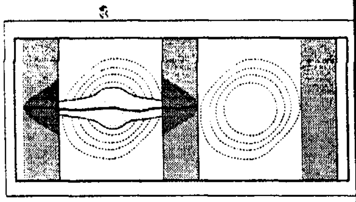
Failure process (QinetiQ) with postbuckling



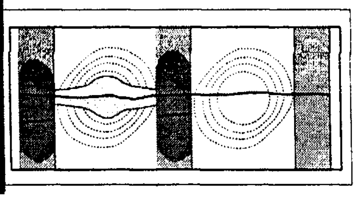
g) Global panel buckling



h) Start of stringer detachment



i) Massive detachment of the stringer



j) Catastrophic panel failure

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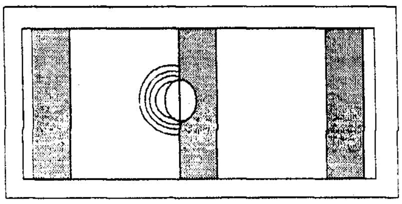
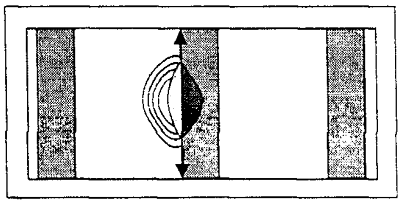
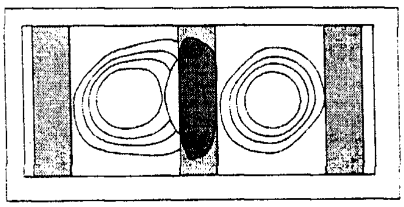
Failure process (QinetiQ)



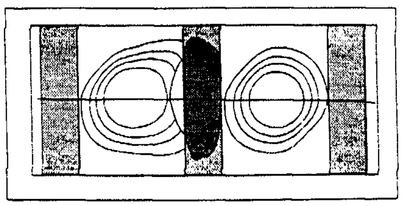
a) Local deformation at the foot



b) Axial extension of the damage



c) Massive detachment of the stringer



d) Catastrophic panel failure

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Analysis methods (ONERA)

1. Methods to represent impact damage
2. Methods to predict delamination buckling
3. Methods to predict the onset of damage growth
4. Methods to predict panel buckling with delamination present
5. Methods to predict skin-stiffener separation
6. Methods to predict transition to unstable growth

ad 1. Model is single delamination and/or soft inclusion
ad 2. Non-penetration condition only in nonlinear analysis
ad 3. Energy release rate considerations
ad 4. Nonlinear analysis
ad 5. New test setup and criteria
ad 6. Releasing nodes or moving mesh

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Test results - QinetiQ

Stiffened panels with artificial delaminations (QinetiQ)
Stiffened panels with impact damage (QinetiQ)

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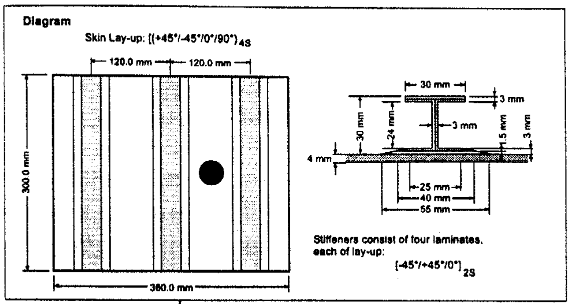
Panel # : Type1_Ins_50x50_45/-45_Bay

Description: Panel SS31

Residual strength test on T800/924 Type 1 stiffened panel containing embedded defect.

Defect was in the bay, 50 mm in diameter (circular) and at the 5/6 (+45°/-45°) ply interface.

The loading is static compression - displacement control



CD Directory		7embss/7_2/7_2_1
Material Data	924prp.doc	Material data for T800/924
Panel Dimensions	ssdim.tif	Panel geometry
	ssfoot.tif	Stiffener foot geometry
	ss#1sg.tif	Strain gauge positions for panel
Impact Data	-	-
Strain Gauge Data	sst1.xls	Data from Test (to failure)
Moiré Data	summ.xls	Summary of the Moiré data
Other	-	-

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Verification of methods (FOI)

1. **Delamination buckle shapes and growth directions successfully predicted**
2. **Prediction of delamination growth onset "fair"**
3. **Good prediction of panel buckling**
4. **Steps taken toward prediction of skin-stiffener separation**

Problems:

1. **Ply failure and delamination ply jumping not predicted**
2. **Imperfections and sublaminate asymmetry not modelled**
3. **Delamination growth not monitored accurate enough during tests**
4. **Coarse grids used at delamination front to limit CPU**
5. **Skin-stiffener separation was not a primary failure mode**
6. **Damage growth instability prediction as yet too difficult**

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Recommendations for use (CIRA)

CIRA-worker left before work was finished: no explicit report.

Contributions incorporated in WP3 report.

Recommendations for use with respect to accuracy and efficiency are rather specific for each method and are not addressed here.

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Assessment (Saab)

1. **Still out of reach:**
   - predicting onset of growth for complicated configurations
   - predicting transition to unstable growth
2. **Buckling predictions good (within 12%)**
3. **Single delamination reduces buckling with 10%**
4. **Delamination growth fair, but tests are needed with higher resolution**
5. **The no-growth criterion is here to stay for many years**
6. **Methods have developed significantly with respect to STATIC damage tolerance requirements**

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Conclusions (NLR)

1. Impact damage simplified to single delamination or area with reduced stiffness
2. Predictions OK for test panels with single delaminations
3. Partners hint at improvements through increased complexity of damage models
4. Hence, partners want more detailed test information regarding damage growth
5. However, the industry stresses the need for reduced complexity
6. Specific numerical techniques developed and available:
   - contact problem
   - re-meshing and moving meshes
7. Improved damage models would require additional numerical techniques
8. At least 8 different codes were used, which inhibits software exchange

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Recommendations (NLR)

Suggestions for future work:

- interaction of postbuckling and damage
- new material configurations
- effect of fatigue loading on damage growth
- impact damage and repair

A new exploratory group (EG 25) has met and ONERA is drafting a proposal

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