



#### Design of Energy-Absorbing CFRP Stanchions for the Cargo Floor Structure of Transport Category Airplanes

2013 Technical Review Paolo Feraboli & Max Spetzler University of Washington

#### Design of Energy-Absorbing CFRP Stanchions for the Cargo Floor Structure of Transport Category Airplanes

#### Motivation and Key Issues

- Airframe-level crashworthiness regulations expected to enter CFR
- Crashworthiness of all-composite structures relatively new topic in aviation

#### Objective

- Streamline certification process
- Develop guidance material

### Approach

 Develop crashworthiness certification protocol for a virtual generic all-composite Part 25 airplane









#### Design of Energy-Absorbing CFRP Stanchions for the Cargo Floor Structure of Transport Category Airplanes

#### **Principal Investigators & Researchers**

- Paolo Feraboli, Research Professor (PI)
- Bonnie Wade (PhD student)
- Max Spetzler (PhD student)

### FAA Technical Monitor

Allan Abramowitz

#### Other FAA Personnel Involved

- Dr. Larry Ilcewicz (Technical Advisor)
- Curt Davies (JAMS Program Manager)

### **Industry Participation**

- Dr. Mostafa Rassaian, Boeing/BR&T (Technical Advisor)
- Kevin Davis, Boeing/BCA (Technical Advisor)









## **Crashworthiness certification protocol**

- Building Block Approach adapted to crashworthiness
- Based on analysis supported by test evidence
- Successfully adopted by Boeing for 787 to meet Special Conditions
- Certification by test not likely to be an option for Part 25 but may be considered for Part 23



**Courtesy: Boeing** 



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### Typical twin-aisle fuselage layout & dimensions

- Separate passenger and cargo floor
- Dimensions largely determined by
  - Passenger space requirements
  - Standard cargo container dimensions
- Cargo floor structure as 'crush zone' to improve vehicle crashworthiness











### Cargo floor structure as 'crush zone'

- Cargo floor stanchions may be designed to absorb energy through progressive crushing in case of a crash
- Dual functionality of stanchions
  - Carry all operational loads according to airworthiness requirements
  - In crash event:
    - 1. Separate from frame
      - 2. Crush on inner skin surface to absorb energy



### **Stanchion separation**

- Three configurations tested to investigate how failure can be triggered at desired location
- Channel-section type stanchions, 190mm long

Type 2

CECAM

Type 3

- T800/3900-2 PW fabric, all 0°
- Displacement control, 50mm/min

10 plies :

8 plies 2

12 plies

6 plies

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Type 1



ransport Aircraft Struct

### **Stanchion separation**



- Failure preceded by local buckling in all cases
- Rupture triggered by any kind of discontinuity
- Interaction between separated pieces
  - Tearing into flat segments







### **Proof of concept with full-length stanchions**

- 4<sup>th</sup> and 5<sup>th</sup> configuration derived from test results
  - Flanges trimmed off to trigger failure and avoid interaction
  - 380mm length
  - Multiple thickness transitions to encourage progressive failure



#### **Proof of concept with full-length stanchions**



## **Stability of progressive crushing - Test**

- Full-length tests showed that crushing is not necessarily stable
- Conditions for stable crushing of interest
- Crushing tests of C-section specimens with varying thickness (6, 8, 10 and 12 plies, all in 0°-direction)



## **Stability of progressive crushing - Test**

- Thick specimens (10-12 plies)
  - Local buckling patterns of low amplitude visible initially
  - Stable crushing
  - High specific energy absorption
- Thin specimens (6-8 plies)
  - Severe buckling of web and flanges throughout process
  - Crushing repeatedly disturbed by rupture at a distance form the crush zone
  - Significantly lower specific energy absorption













### **Stability of progressive crushing - Test**

- Crushing under buckling deformation coincides with unsteady part force-displacement curves
- Laminate failure outside of crush zone causes load to drop and reduces energy absorption



- Finite element model of specimen (LS-DYNA)
  - 2.5mm mesh size, fully integrated shell elements (type 16), MAT54
  - Nodes constrained at location of hydraulic grips
  - Edge load applied at other end (Represents load imposed onto specimen by the crush zone)
  - Loaded edge 'pinned'
- Length of specimen varied
- Two types of analysis
  - 1. Implicit buckling analysis (eigenmode analysis)
  - 2. Explicit non-linear failure load analysis



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- Both analysis types predict buckling patterns (pictures from non-linear analysis)
- Failure location (non-linear analysis) depends on laminate thickness
  - 6-8 plies
- at a distance  $\rightarrow$ from crush zone
- 10-12 plies  $\rightarrow$  at loaded edge









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# Conclusion

- Typical transport category airplanes feature stanchions in the cargo floor structure, which can be designed to improve crashworthiness of the airframe
- Energy absorption through progressive crushing of CFRP stanchions requires certain design features in the stanchions
- To increase energy absorption, the C-channel stanchions need to separate from the structure on one side so that they may subsequently crush
- A discontinuity (thickness transition, change of flange height) at the desired location can trigger separation after local buckling of web and flanges
- Stable crushing requires that the laminate does not fail outside the crush process zone
- Buckling and failure loads obtained from finite element analysis may be used to assess if crushing will be stable or not



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### **Looking Forward**

Subcomponent-Level Test and Analysis







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# **Looking Forward**

#### **Benefit to Aviation**

- Provide guidance for certification process
- Increase confidence and therefore level of safety

### Future needs

Guidance material for all levels of the BBA









# **End of Presentation.**









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