Discovery Channel Plane Crash

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Objectives

Visualize Crash Test Sequence

Aircraft Interior Regulations
  • Survivability / Design Limits

Crash Pulse
  • B727 Crash vs Reg’s

Conclusions/Observations
Aircraft on Approach, Pilots Parachute Out
B727 Controlled by Remote (Chase Aircraft)
Historical Perspective

9/23/62 Lockheed Constellation Accident
NTSB Investigation Concluded:
Interior/Seats hindered evacuation

1981 NTSB Study (NTSB-AAS-81-2)
Surveyed 77 Survivable accidents 1970 to 1980
Poor cabin design contributed to fatalities in 60% of the accidents
Regulations, How are they doing?

• 1989 Dynamic Impact Regulations

• 2000 FAA Cost / Benefit Study (DOT/FAA/AR-00/13)

• 2005 Operational Rule (effective Oct. 2009)
  • New A/C Deliveries

• Is Test Standard Representative?
Video: External (Geo-Stabilized Helicopter)
Discovery Plane Crash Data

- **Video (Go Pro and High Speed) - All**
- **String Pots (Floor Crush) - Barth**
- **Floor Accelerations - Barth**
- **Test Dummies – Dr. Cindy Bir Wayne State Univ., Barth**
- **General Flight Dynamics / Structure – Prof. John Hansman, MIT**
- **General Accident / Black Box – Anne Evans, former senior acc. inv., AAIB UK**
String Pots
Forward Cargo

Sensors
Row 13, 20, 27

Instrumentation Box

Trigger: 10g latching switch, vert.
- High Speed Video
- Test Dummies
- Accelerations (DTS E-Slice)
## Emergency Landing Conditions

### Test 1: Downward / Forward
- **GA Aircraft**
  - $t_p = 0.050$ s (crew)
  - $t_p = 0.060$ s (pass.)
  - $g_{p} = 19$ g (crew)
  - $g_{max} = 19$ g (pass.)
  - $\Delta V = 9.5$ m/s
- **Transport Aircraft**
  - $t_p = 0.080$ s
  - $g_{p} = 14$ g
  - $\Delta V = 10.7$ m/s (passenger)
- **Rotorcraft** (all)
  - $t_p = 0.031$ s
  - $g_{p} = 30$ g
  - $\Delta V = 9.1$ m/s

### Test 2: Forward / Lateral
- **GA Aircraft**
  - $t_p = 0.050$ s (crew)
  - $t_p = 0.060$ s (pass.)
  - $g_{p} = 26$ g (crew)
  - $g_{p} = 21$ g (pass.)
  - $\Delta V = 12.8$ m/s
- **Transport Aircraft**
  - $t_p = 0.090$ s
  - $g_{p} = 16$ g
  - $\Delta V = 13.4$ m/s (passenger)
- **Rotorcraft** (all)
  - $t_p = 0.071$ s
  - $g_{p} = 18.4$ g
  - $\Delta V = 12.8$ m/s

### Diagram
- Acceleration ($g$) vs. Time (s)
- Yaw right or left
- 30°
Occupant Survivability

- **Cockpit**
  - Survivable Space
  - High Impact Loads

- **Rows 1-7 (Right) & 1-11 (Left)**
  - Non-Survivable

- **Rows 8-16 (Fwd of Wing),**
- **Rows 17-23 (Overwing),**
- **Rows 24-32 (Aft of Wing),**
  - All Intact, All Survivable
  - Evacuation Issue with Cables
Cockpit Video
Large Aircraft Crash Test Challenges

- Impact time / Duration
  - Methods: Best Fit, 5% of Peak G, other…

- Response Relative to Location
  - Force, Velocity, Crush, Residual Velocity
Example: Best Fit, Each Component (X, Z)

- Triangle Shape
- Qualitative Assessment of Fit
- Qualitative Assessment of Primary Impact
- "Primary Impact" – Data Exhibited:
  - Impact < 0.200s, (followed by trend toward zero, then transient to smaller, secondary peak)
- Also Looked at:
  - Polynomial Fit, Moving Avg, Averaged Rows
Row 13 Floor Accelerations

X Peak $\approx 11.5$ g, at $\approx 0.052\text{s}$, Onset $= 221$ G/s

Y Peak $\approx 5.7$ g, at (NA)

Z Peak $\approx 8.6$ g, at $\approx 0.077\text{s}$, Onset $= 112$ G/s
Row 20 Floor Accelerations

X Peak = ~7.1 g, at ~ 0.061s, Onset = 116 G/s

Y Peak = ~5.1 g, at (NA)

Z Peak = ~9.6 g, at ~ 0.033s, Onset = 291 G/s
Row 27 Floor Accelerations

X Peak =~4.4 g, at ~0.065s, Onset = 68 G/s

Y Peak = ~9.2 g, at (NA)

Z Peak =~13.4 g, at ~0.091s, Onset = 147 G/s
Results: Best Fit, Each Component (X, Z)

- Not Satisfied
- Too Much Interaction between X and Z
- Conclusion: Use Resultant

Resultant = \sqrt{x^2 + y^2 + z^2}

- Initial time based on 5% of Peak Acceleration
- Total Duration set at Double Time to Peak
Row 27 Resultant
Resultant = \sqrt{x^2 + y^2 + z^2}

• Method: OK

• Limitations:
  • Neglects Large Portion of Impact
  • Specific to Aircraft Cabin Section
    (Forward, Overwing, Aft)

New Modifications

• Allow Transient, Longer Pulse
• Average the Resultants of Rows 13, 20, 27
Avg Resultant Rows 13, 20, 27

Average of Resultants X, Y, Z
Acceleration
Velocity

Graph showing acceleration and velocity over time.
Plane Crash “Ideal” Impact Pulse

Average of Resultants X, Y, Z

Acceleration
Velocity
Regulatory Comparison

- Peak G about 30% lower than Regulatory
- Onset Approximately 120 G/s
  - Transport Aircraft Pulses ~ 175 G/s
  - General Aviation Pulses ~ 350 to ~ 520 G/s
- Total Velocity Change
  - About Double the Regulatory Pulses
Conclusions

• Plane Crash Test
  • Well within Design Limits
  • Clearly Long, Drawn out Impact (for most of Cabin)

• Plane Crash “Ideal” Pulse Reasonable

• Regulatory Pulses
  • Good Representation of Survival / Design Limits
  • Represent only Primary Impact (Capture Only Small Portion of Total Velocity)
Observations

• Influence from Experiment and Test Equipment Limitations? (Velocity/Crush)

• Typical Survivable Crash
  • Long and Drawn out
  • Primary Impact Mitigated

• Need Better Understanding of:
  • Secondary Response
  • Cumulative Effects
Thank You!

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