ASSESSMENT OF LUMBAR TENSION LOADS IN A FORWARD FACING SEAT CONFIGURATION USING BOTH HYBRID II AND FAA HYBRID III ATDS

OCTOBER 28-31, 2019

PRESENTED TO: THE NINTH TRIENNIAL INTERNATIONAL AVIATION FIRE AND CABIN SAFETY RESEARCH CONFERENCE

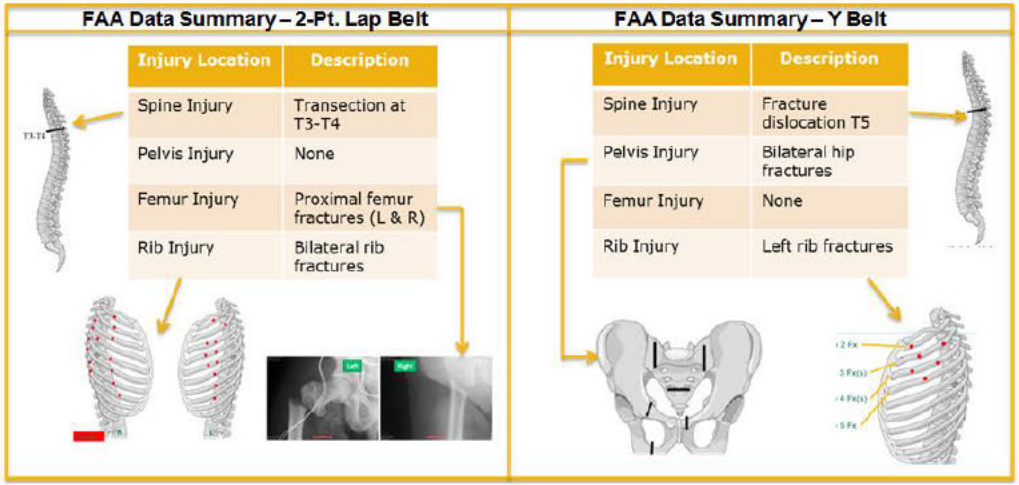
BY: JEFF THOMPSON
COLLINS AEROSPACE

Collins Aerospace

MOTIVATION

CHANGING REGULATIONS, QUALIFICATIONS, AND RESEARCH AROUND SPINAL TENSION

- FAA performed a study supporting development of spinal injury criteria for oblique seating [1].
- An additional study comparing Y-Belt and Standard 2-pt Belts discovered potential spinal tension injuries when an occupant does not impact a seat or monument [2].
- Implemented Spinal Tension requirements for Oblique Seating as Special Conditions



[1] Humm J, Moorcroft D, Yoganandan N, DeWeese R, Taylor A, Pintar F. Preliminary FAA-Hybrid III Spinal Injury Criteria for Oblique-Facing Aircraft Seats. ASME. ASME International Mechanical Engineering Congress and Exposition, *Volume 3: Biomedical and Biotechnology Engineering* ():V003T03A059. doi:10.1115/IMECE2015-52059.

[2] Humm J, DeRosia J, Pintar F, Yoganandan N, Taylor A, Moorcroft D, DeWeese R, Peterson B. Comparison of Standard and Y-Belt Aircraft Passenger Restraints in Frontal Impacts with PMHS and ATD. The Eighth Triennial Interna ional Fire & Cabin Safety Research Conference, 2016.

TEST CAMPAIGN

Progressive evaluation of knee stops:

- FAA H3 with knee stops removed
- FAA H3 with standard knee stops
- FAA H3 with reinforced knee stops
- H2 with standard knee stops

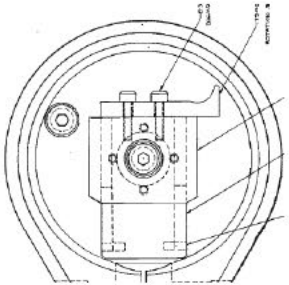
Infinite Setback Configuration

No contact with forward structure

Collins Aerospace

TEST SETUP

- 0 yaw, 16g, Infinite Setback
- Typical 2-pt lapbelts*
- Started with FAA H3
- Key measures
  - Lumbar tension
  - Seatbelt loads
- H3 knee stops were left out initially due to historical tendency to break
  (+ kick panels)



[3] Parts List and Drawings Subpart E HYBRID III 50th PERCENTILE MALE. APRIL 1997. OFFICE OF CRASH WORTHINESS STANDARDS AND VEHICLE RESEARCH and TEST CENTER. NATIONAL HIGHWAY TRAFFIC SAFETY ADM NISTRATION.

Broken post-test knee stop

Collins Aerospace

STANDARD KNEE STOPS VS NO KNEE STOPS / H3

Std Knee Stops (Solid Curves)

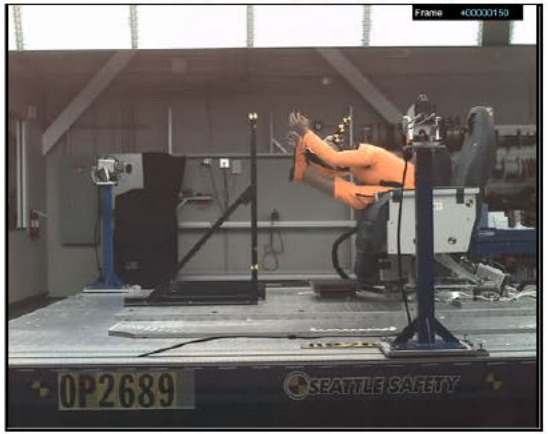
No Knee Stops (Dashed Curves)

- Knee stops broke early after contact (in line with historical expectations)
- Kinematics appeared visually non-biofidelic for both cases
- Increased lumbar tension with standard knee stops → Indicates possible Spinal Tension Relationship

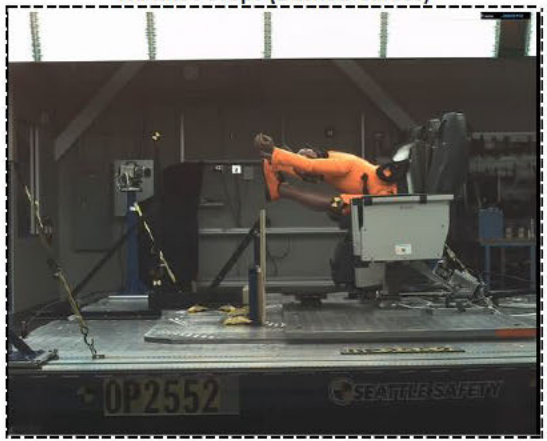
Collins Aerospace

REINFORCED KNEE STOPS VS NO KNEE STOPS

Reinforced Knee Stops (Solid Curves)



No Knee Stops (Dashed Curves)



- Prototype knee stops >> stiffer, installed on both sides of knee
- Kinematics appeared more realistic
- Knee stops did not break, but there were post-test stress indications
- Sudden lumbar spike at exact instant that knees locked

Collins Aerospace

FEMUR MOMENTS

- First test to measure femur moments
- Spiked at same instant as knee lock
- Substantial moment into femurs
- Provides another indication of the relationship between dynamic knee stop and lumbar tension

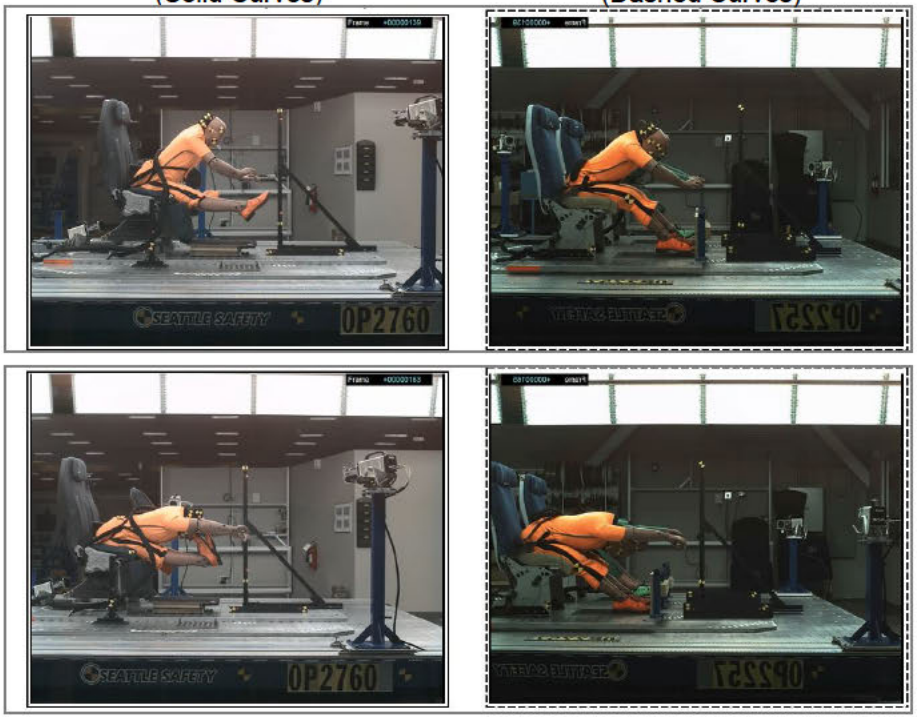
Collins Aerospace

REVISIT H2 ATD

- H2 has more robust knee stops
- Two distinct spikes without kick panels
  - 1st - knee stop
  - 2nd – upper body flail
- Indicates a portion of lumbar tension is attributable to dynamic knee lock

Without Kick Panel
(Solid Curves)

With Kick Panel
(Dashed Curves)



* Illustrative Data

Collins Aerospace

KEY POINTS AT THIS JUNCTURE

- Relationship observed between knee stops and lumbar tension
- Observed two major contributors to lumbar tension – dynamic knee lock, upper body flail

Follow-up Questions

- What is biofidelic behavior for knee stop?
- How would a more biofidelic knee stop impact lumbar tension?

WHAT IS BIOFIDELIC BEHAVIOR FOR KNEE STOP?

Survey literature for possible insight

- [4] Meyer, E.G., Baumer, T.G., Haut, R.C.: Pure Passive Hyperextension of the Human Cadaver Knee Generates Simultaneous Bicruciate Ligament Rupture. Journal of Biomech. Eng. 2010 Dec: 133(1): 011012. Copyright © 2011 by ASME
- Human knees loaded in hyperextension until gross injury
- Includes measurements for bending moments and extension angle

⇒ Next model similar behavior in FEA

ASSESS MORE BIOFIDELIC KNEE STOP BEHAVIOR

FINITE ELEMENT ANALYSIS

- Modified knee stop math model

  Linear ramp from 0 N-m at 0° to 108 N-m at 33.6°, then step change to 0 N-m after 33.6°

- Results support hypothesis that ATD lumbar tension is influenced by knee stop behavior.
- Results also suggest standard H3 knee stops (red) may provide a ROM approximation for more biofidelic knee stops (green) ⇒ further study needed.
- ATD knees still exhibit substantial extension angle with this approximation.

[5] Humanetics FAA H3-50TH DUMMY LS-DYNA MODEL, Version 1.2.3

Collins Aerospace

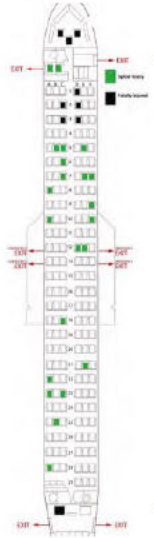
CAMI/MCW RESEARCH AS A REFERENCE POINT

- [2] Humm J, DeRosia J, Pintar F, Yoganandan N, Taylor A, Moorcroft D, DeWeese R, Peterson B. Comparison of Standard and Y-Belt Aircraft Passenger Restraints in Frontal Impacts with PMHS and ATD. The Eighth Triennial International Fire & Cabin Safety Research Conference, 2016.
- PMHS tests conducted in similar configuration with no reported knee anomalies

Collins Aerospace

SURVEY OF CRASH INJURY DATA

Turkish Airlines
Flight 1951



20 Passengers with spinal injuries

Asiana Airlines
Flight 214

55 Passengers with any spinal injury

24 with significant spinal injuries (one did not survive)

- References to a number of spinal injuries
- Also references to minor injuries in general

⇒ *However, no specific indication of knee injuries*

[6] Poland K, McKay M, Taylor, A. Passenger Spinal Injuries in the 2013 Asiana and 2009 Turkish Airlines Crashes. The Eighth Triennial International Fire & Cabin Safety Research Conference, 2016.

[7] NTSB. Descent Below Visual Glidepath and Impact With Seawall Asiana Airlines Flight 214 Boeing 777-200ER, HL7742 San Francisco, California July 6, 2013. NTSB/AAR-14/01 PB2014-105984

[8] The Dutch Safety Board. Crashed during approach, Boeing 737-800, near Amsterdam Schiphol Airport, 25 February 2009. Project number M2009LV0225_01

Collins Aerospace

SUMMARY

- Testing has revealed a relationship between dynamic knee stop and lumbar loads
- Dynamic knee locking with lower leg flail corresponded with increased ATD lumbar tension
- Phenomenon was observed both in H2 and FAA H3 ATDs
- FAA H3 ATD knee stops are relatively fragile with questionable biofidelity
  - ⇒ *Free flail viewed as beyond original intended purpose for H2 and FAA H3 ATD knees**
- An FEA study supported hypothesis that knee stop behavior impacts ATD lumbar tension
  - ⇒ *The same FEA study also suggested standard H3 knee stops may provide an approximation for more biofidelic knee stops, although further study is needed.*
- A survey of CAMI/MCW research and crash data revealed no prominent indication of knee specific injuries for this particular load case.

ACKNOWLEDGEMENTS

THANKS TO THE FOLLOWING FOR THEIR CONTRIBUTIONS AND SUPPORT:

FRANK H. FANG PH.D.
NENG YUE
SANTOSH RAJA

RANDY PENLEY
RON GRILLIOT

GREG SIMECEK

RICK DEWEESE
DAVID MOORCROFT

Collins Aerospace