IMPACT BIOMECHANICS

HYBRID III RESPONSE IN A SAE® BAJA VEHICLE UNDER FRONTAL IMPACTS

Introduction

- The SAE Baja is a student design competition where participants design and build an off-road vehicle.
- The competition involves number of off-road events to challenge student's designs.
- SAE Baja rules require the driver to wear a SFI 3.3 rated arm restraint and neck collar, Snell M2000 standard helmet, and a SFI/FIA rated four point seatbelt.
- The rules stipulate minimum chassis frame requirements to ensure the roll cage is adequate to protect the occupant.
- A top speed of 10.3 m/s (37kph/23mph) was recorded in the acceleration & speed event of the 2005 competition.

Research Goals

- To assess injury risks to the occupant in a Baja vehicle during frontal impacts.
- To develop an understanding of modeling a crash scenario.

Methods

Simulation Setup

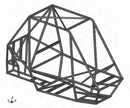
- An explicit finite element program (LS-Dyna, LSTC) was used to simulate a frontal impact into a rigid wall.
- 2.5 m/s, 5 m/s and 10 m/s initial vehicle impact velocities were simulated. Each set of velocities were simulated with and without a neck collar, total of 6 simulation runs.
- The tubular chassis frame, seat, seatbelt, helmet, neck collar, and occupant were modeled to closely mimic driving conditions.
- Non-structural components were modeled as point masses.

Injury Evaluation

- Different criteria were used to evaluate injury risk to the driver, the thresholds were based on NHTSA frontal Impact Standard, FMVSS 208.
- Chest Injury criteria evaluates injury based on peak chest compression and peak acceleration.
- Head Injury Criterion (HIC15) evaluates head injury based on translational acceleration of the head over 15 msec.
- Neck Injury Criterion (N_{ij}) evaluates neck injury based on axial neck loads and neck joint moments.

Chassis

- Modeled after 2006 UW Baja vehicle
- AISI 1018 Steel frame



Helmet

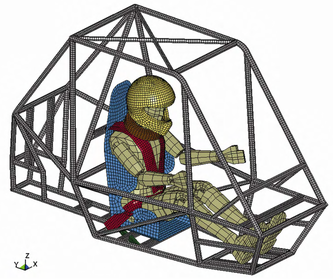
- Modeled as rigid bodies
- 1.7 kg mass (measured)
- Constrained to head model

Neck Collar

- Based on SFI 3.3 collar geometry
- Polyethylene foam density 80 kg/m^3 (measured)
- Material model: *Mat_low_density_foam
- Material response based on Ouellet et al's data

Injury Criteria

Chest Compression	63mm
Chest Acceleration	60G
Head Injury Criterion (15ms)	700
Neck Injury Criterion	1.0

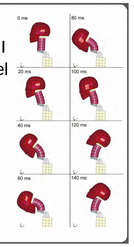


Vehicle Mass Breakdown

Chassis	61.5 kg
Non-structural	143.5 kg
Hybrid III Dummy	78.9 kg
Total	**283.9 kg**

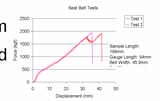
Hybrid III Dummy Model

- Based on 1997 LSTC Hybrid III deformable finite element model
- 50th percentile male
- Neck response validated against NHTSA test procedure, TP-208-13
- Simulation conditions derived from Yang et al's paper (1993)



Seatbelt

- Four point harness system
- Material behavior modeled after seatbelt tensile test

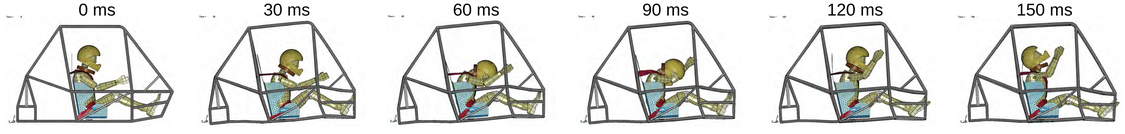


Seat

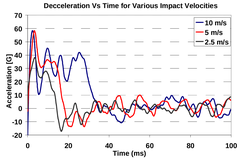
- Simplified Seat Geometry
- Seat stiffeners and padding not modeled

Results

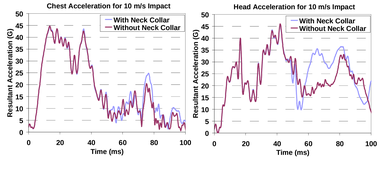
Crash Sequence



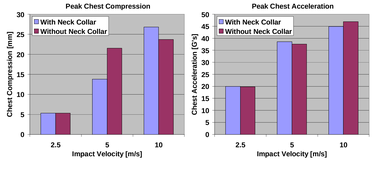
- The following figure shows vehicle response in terms of acceleration between three impact velocities.



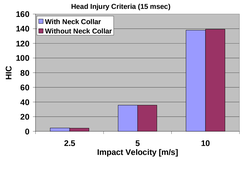
- Little difference was noted between initial acceleration response of occupant's chest and head, with and without neck collar in a high velocity impact.



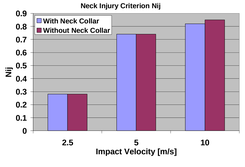
- Maximum chest acceleration was 46.9G and compression was 26.8 mm. (Injury criteria: 60G and 63 mm)



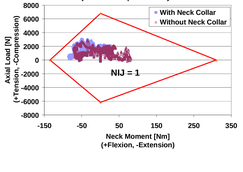
- HIC values were below the threshold of 700, with values ranging 4.3 to 139.
- The neck collar did not significantly change head injury results.



- Nij values were below the threshold of 1, with maximum recorded value of 0.82 without neck collar and 0.85 with neck collar.



- Neck response overall overlaps between cases with and without neck collar.
- High tensile neck axial load with extension moment is most probable injury mode.



Discussion

Thoracic Injury

- Chest compression and acceleration were below thresholds for all cases.

Head Injury

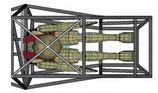
- The neck collar did not significantly change head injury results.

Neck Injury

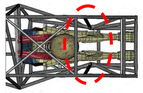
- The neck collar did not significantly change neck injury results, in agreement with physical hybrid III testing with different neck collars by Glaister et al.

Chassis Structural Integrity

- Consider chassis geometry where side impact tubing may buckle inward and into the occupant under high velocity impact conditions.

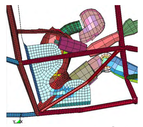


Before Crash



During Crash

- Improper bracing support to the seatbelt mounting points result in submarining of occupant, increasing the possibility of abdominal injury.



Proper restraint

Improper restraint

Limitations

- Due to simplified helmet and seat model, the flexion effect of the head and contacting the seat during rebound is not modeled.
- The geometry of the Hybrid III model may limit its applicability of evaluating neck collar.
- Physical testing is needed to validate the chassis frame response.

Conclusions

- In all cases studies, no injuries were predicted based on simulation results and accepted injury thresholds.
- Nij appeared to be the most probable injury in higher velocity crashes. Contributors to increased Nij values include a stiff vehicle chassis, which the occupant is tightly restrained to, no crush structure, and added helmet mass to the head.
- Including lateral impact and rollover simulations would be useful for the development of the Baja competition vehicle requirements.

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