Development of Rotational Brain Injury Criterion (BRIC)

Human Injury Research Division
Procedure

• Develop validated human brain FE model (SIMon)
• Use CSDM as a biomechanical rotational injury criterion
• Use side impact tests with ES-2 dummy and frontal impact tests with HIII dummy instrumented with NAP (make sure the measurements are correct)
• Run SIMon with the measurements from ES-2 and HIII and calculate CSDMs
• Correlate CSDMs with kinematic parameters - a combination of angular acceleration and angular velocity such that the value of 1.0 corresponds to 30% of probability of DAI
• Use the same procedure with WorldSID
Procedure

• Develop validated human brain FE model (SIMon)
• Use CSDM as a biomechanical rotational injury criterion
• Use side impact tests with ES-2 dummy and frontal impact tests with HIII dummy instrumented with NAP (make sure the measurements are correct)
• Run SIMon with the measurements from ES-2 and HIII and calculate CSDMs
• Correlate CSDMs with kinematic parameters - a combination of angular acceleration and angular velocity such that the value of 1.0 corresponds to 30% of probability of DAI
• Use the same procedure with WorldSID
• Over 45,000 elements

• 42,500 nodes – solves ~ 120,000 equations simultaneously every microsecond

• Takes 10 hours on high-end workstation to simulate 150 ms loading event

• Utilizes the latest knowledge of material properties of various tissue
Procedure

- Develop validated human brain FE model (SIMon)
- Use CSDM as a biomechanical rotational injury criterion
- Use side impact tests with ES-2 dummy and frontal impact tests with HIII dummy instrumented with NAP (make sure the measurements are correct)
- Run SIMon with the measurements from ES-2 and HIII and calculate CSDMs
- Correlate CSDMs with kinematic parameters - a combination of angular acceleration and angular velocity such that the value of 1.0 corresponds to 30% of probability of DAI
- Use the same procedure with WorldSID
Cumulative Strain Damage Measure (CSDM)

30% probability of DAI -> CSDM (0.25) = 0.425
Cumulative Strain Damage Measure (CSDM) for each AIS
BRIC Formulation

\[ BRIC = \frac{\omega_{\text{max}}}{\omega_{\text{cr}}} + \frac{\alpha_{\text{max}}}{\alpha_{\text{cr}}} \]

\( \omega_{\text{max}} \) and \( \omega_{\text{cr}} \) -> maximum and critical rotational velocities respectively

\( \alpha_{\text{max}} \) and \( \alpha_{\text{cr}} \) -> maximum and critical rotational accelerations respectively
Procedure

- Develop validated human brain FE model (SIMon)
- Use CSDM as a biomechanical rotational injury criterion
- Use side impact tests with ES-2 dummy and frontal impact tests with HIII dummy instrumented with NAP (make sure the measurements are correct)
- Run SIMon with the measurements from ES-2 and HIII and calculate CSDMs
- Correlate CSDMs with kinematic parameters - a combination of angular acceleration and angular velocity such that the value of 1.0 corresponds to 30% of probability of DAI
- Use the same procedure with WorldSID
Results (Frontal Impact Tests with HIII Dummy)
Results (Side Impact Tests with ES-2re Dummy)
Results (Side Impact Tests with WorldSID Dummy)
Discussion

• BRIC is different for different dummies and human athletes.

• Concussive (AIS 2+) values of BRIC for humans varied from 0.60 when scaled directly from animal data (Ommaya, 1985) to 0.68 when obtained directly from the college football players.

• The risk of AIS 3+ TBI for BRIC = 0.68 when using the Hybrid III dummy as an assessment tool is approximately 1%, when using ES-2re dummy it is approximately 7%, and when using the WorldSID it is also about 8%.

• BRIC for the 30% risk of AIS 3+ TBI is 0.92 if measured with HIII dummy, 0.89 if measured with ES-2re and WorldSID dummies.

• BRIC should be used in combination with HIC. However, the risk of TBI for combination of rotational and translational loading modes should be investigated in the future.