THE OHIO STATE UNIVERSITY

COLLEGE OF ENGINEERING

CHARACTERIZATION OF FRICTION FOR HUMAN IMPACT SIMULATION IN VEHICLE CRASH APPLICATIONS

SIMCenter

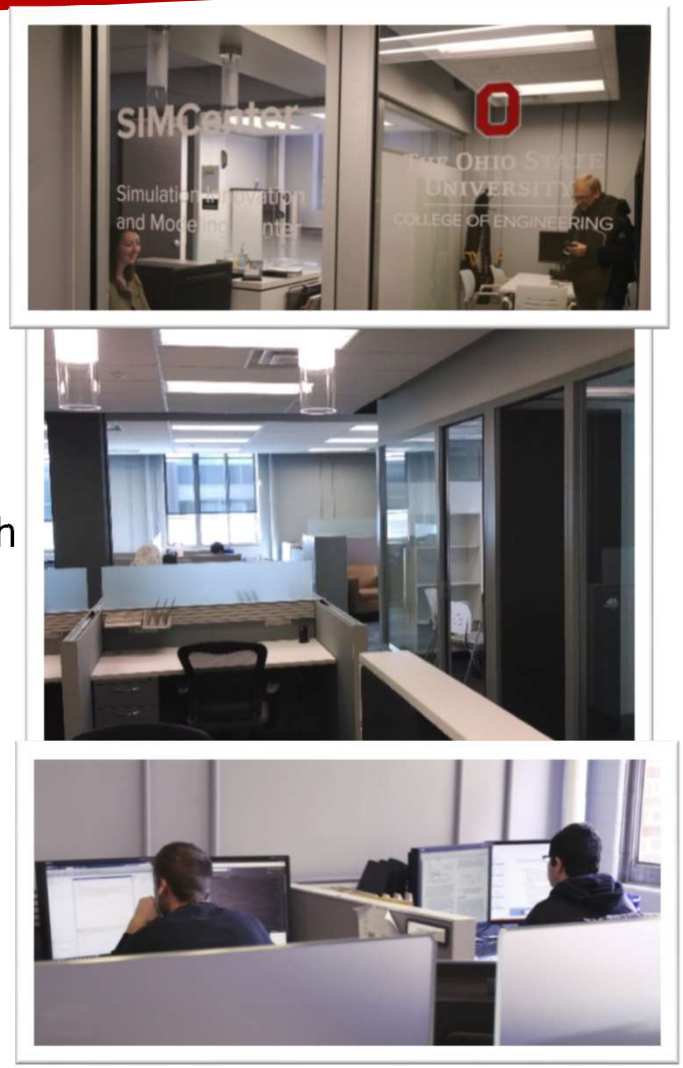
HONDA
The Power of Dreams

Sheng Dong *The Ohio State University*
Allen Sheldon *Honda R&D Americas, Inc*

COLUMBUS, OHIO, USA

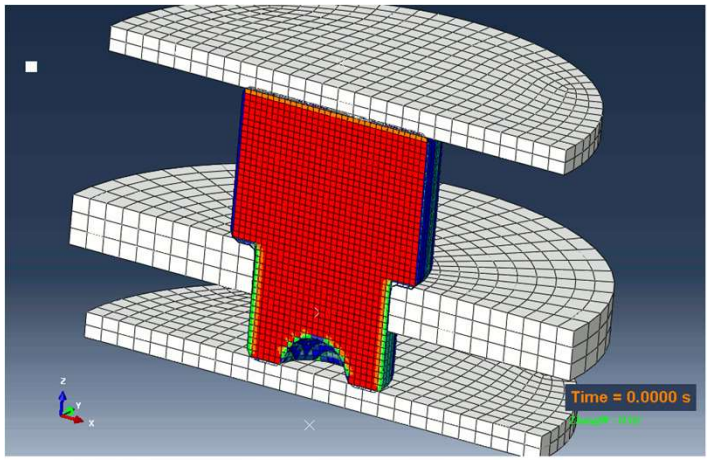
Simulation Innovation Modeling Center

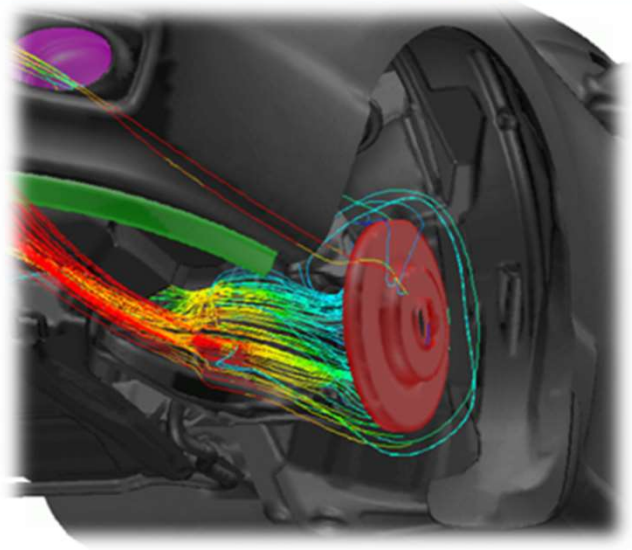
- Mission:
  - To advance computer-aided engineering techniques for Research, Design, and Manufacturing in industry
  - Main focus is on transportation
- Status:
  - Initial facilities renovation completed 2/10/2014
  - $5 million in seed money from Honda with match from OSU
  - 2nd expansion completed Fall 2015
  - Experimental lab spaces created Spring 2016
- Resources:
  - High-performance computing (HPC)
  - Industry grade software
  - Application experts
  - Faculty with industry experience



SIX THRUST AREAS

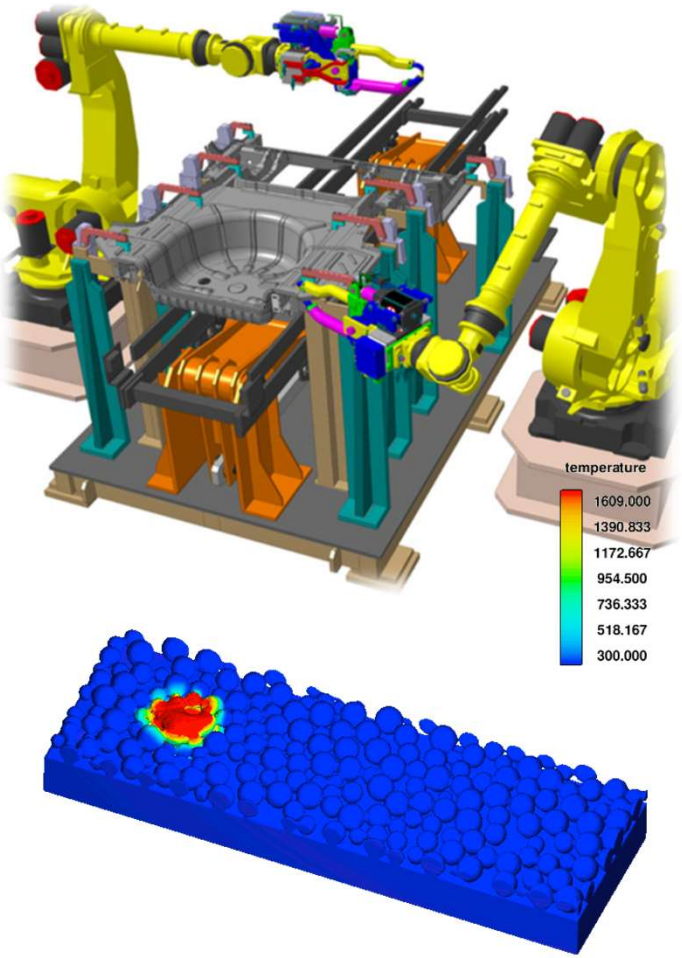
- Computational Solid and Structural Mechanics
  - Modeling of mechanical systems of complex geometries and joining techniques under linear and non-linear deformation
- Computational Fluid Mechanics
  - Accurate performance prediction of steady-state and time-dependent external, internal flows, and acoustics
- Optimization and CAE Automation
  - Use of optimization techniques to automate and enhance the use of CAE tools





SIX THRUST AREAS

- Digital Manufacturing
  - Manufacturing system and process modeling to improve cost, efficiency, and quality
- Multi-Physics Simulations
  - Reduced fidelity models across multiple domains to capture interactions between mechanical, electrical, and controls domains
- Systems Modeling, Integration, and Control
  - System-level plant and control models to model interconnected systems to accelerate the development process

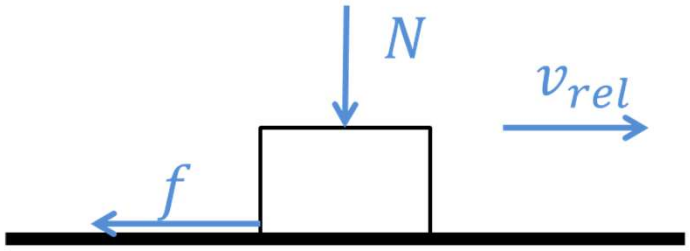


OUTLINE

- Introduction and motivation
  - Friction
- Modeling friction
- Friction measurements
- Impact models with corresponding measurements
  - Head form on engine hood
  - Head form on roof liner
  - Head form on inside of B pillar
- Concluding remarks

FRICTION

- Friction is the resistance to the motion between two contacting surfaces when they slide or roll relative to each other



- Three empirical laws of friction
  - Friction is proportional to the normal force
  - Friction is independent of nominal area
  - Friction is independent of the velocity (not always hold)

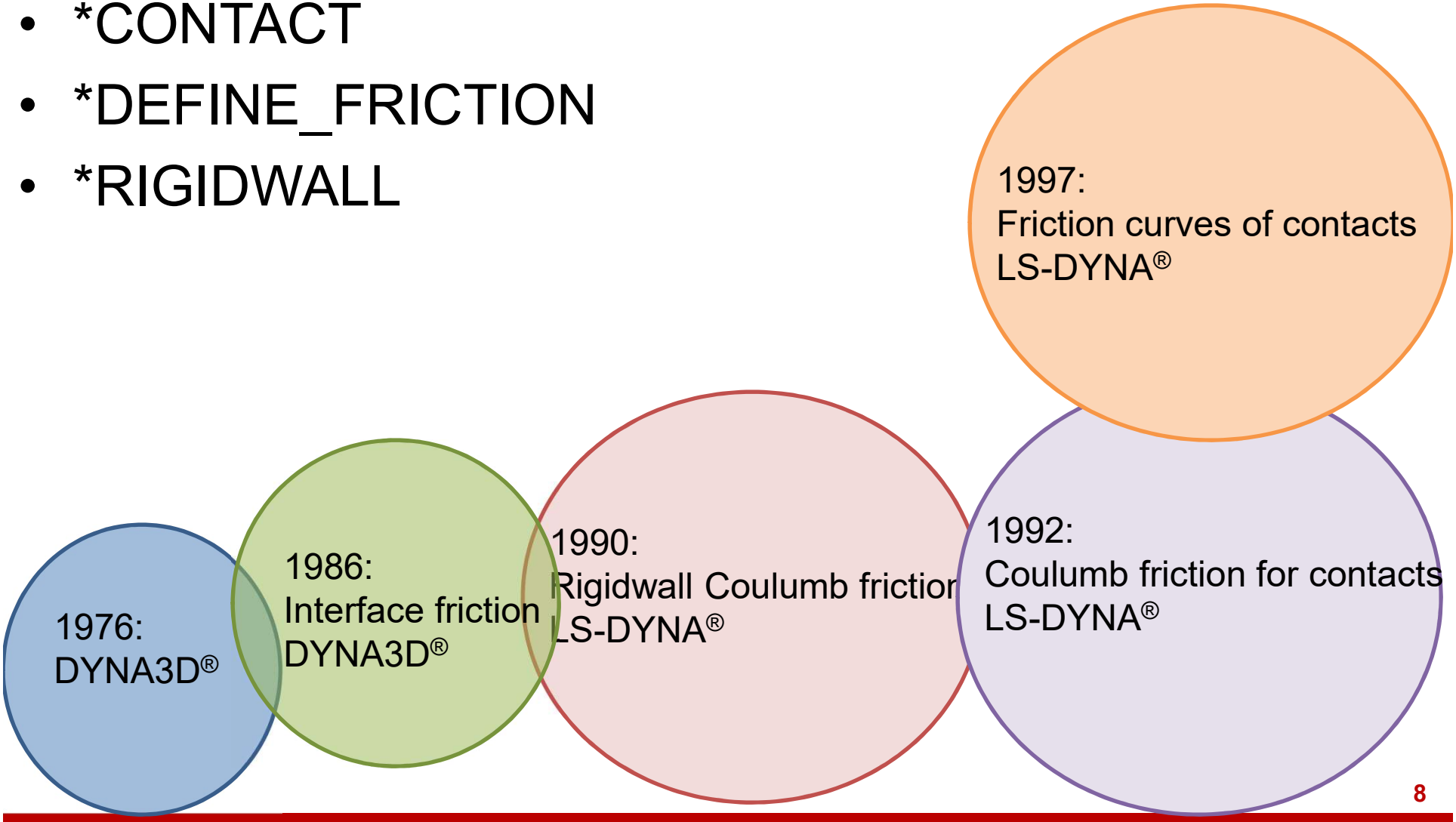
- Coulomb friction model

$$f = -N\mu\,\mathrm{sgn}(v_{re})$$

where μ is the coefficient of friction, v_{re} is the relative sliding velocity and *N* is the normal force.

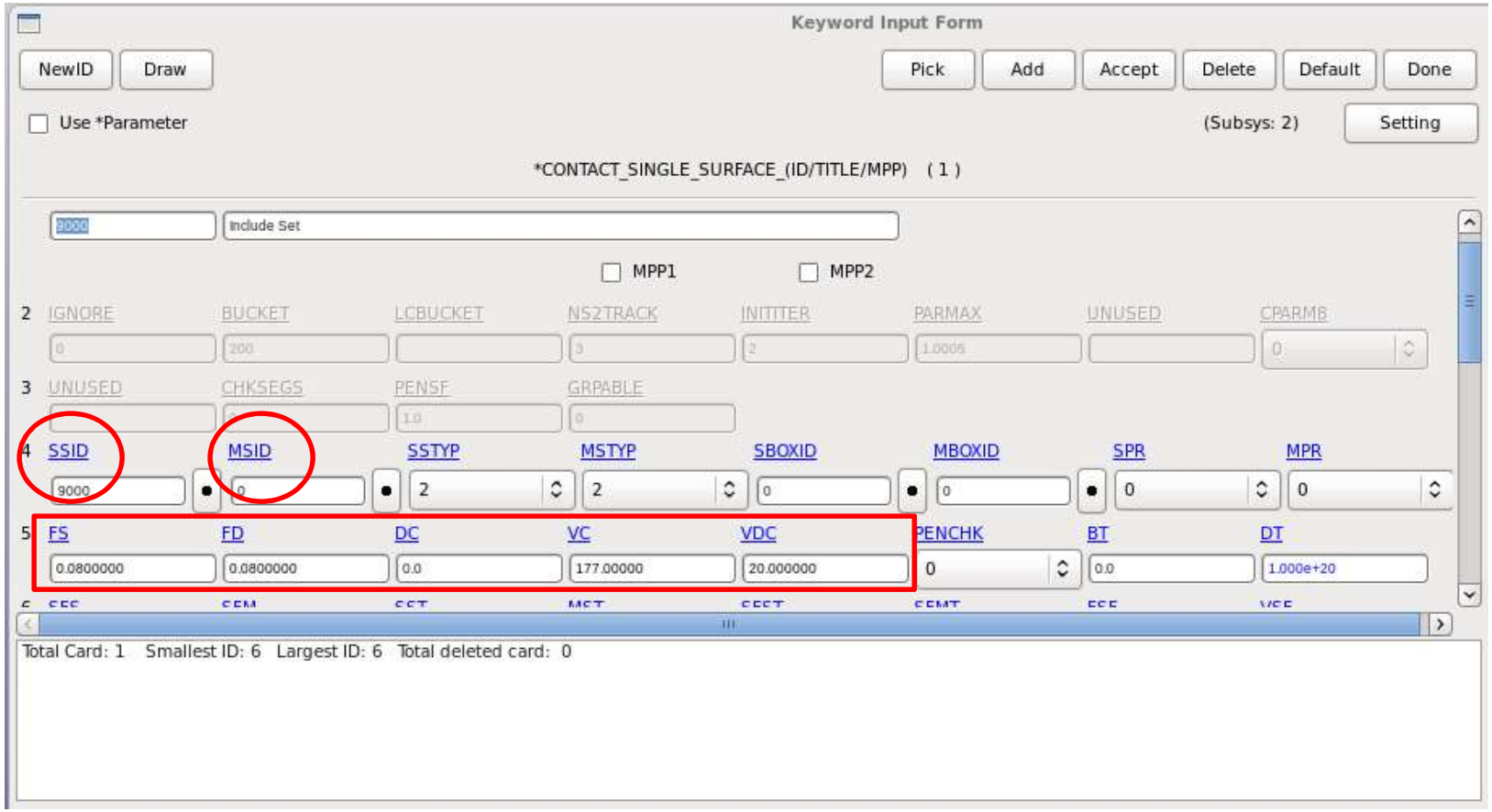
DEFINE FRICTION IN LS-DYNA®

- *CONTACT
- *DEFINE_FRICTION
- *RIGIDWALL

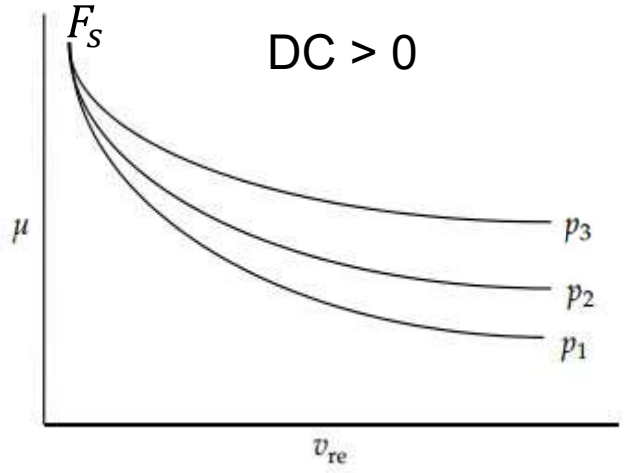


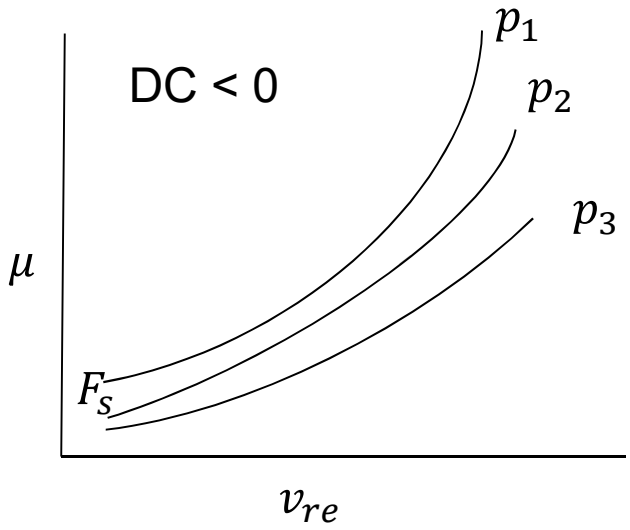
DEFINE FRICTION IN CONTACTS

*CONTACT
Define friction for all the parts/part sets that use this contact

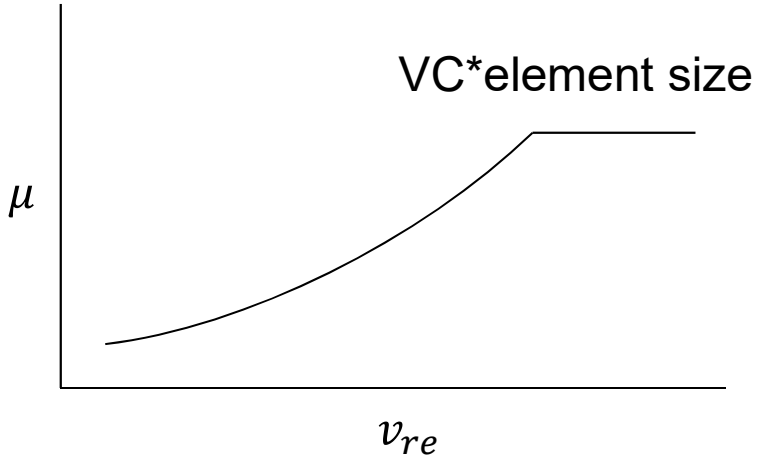


FRICTION – VELOCITY CURVES



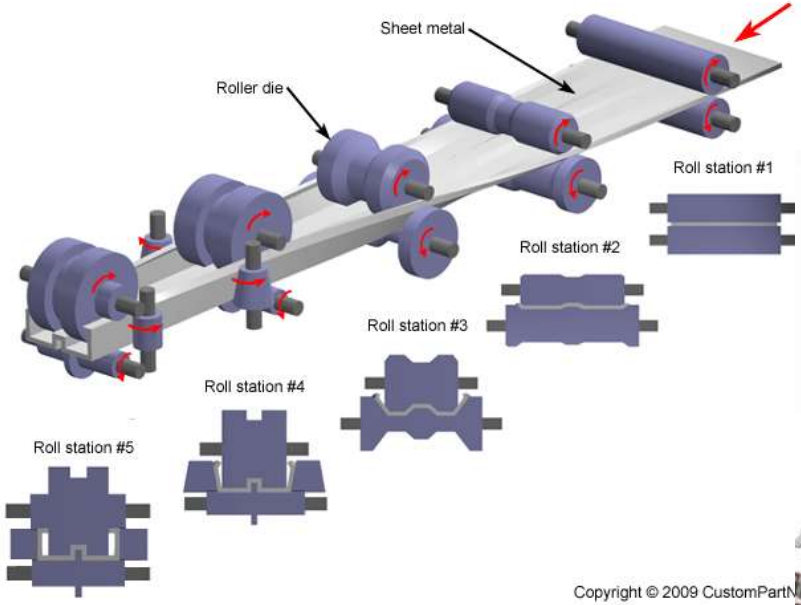


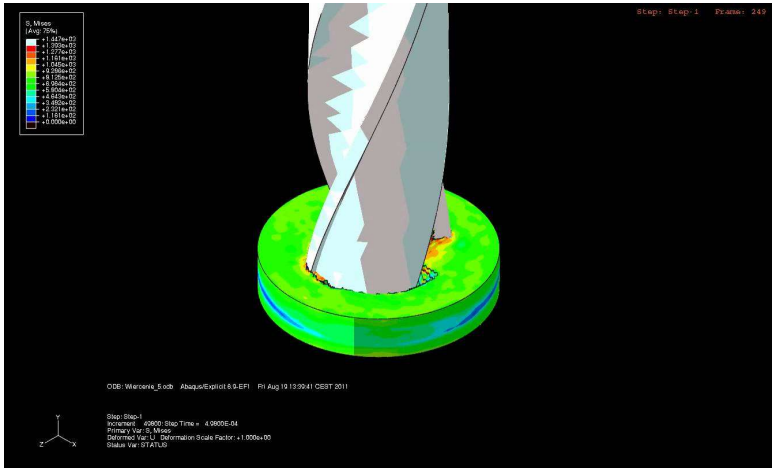
$$\mu = F_D + (F_S - F_D)e^{-DC|v_{rel}|}$$



VDC is a damping coefficient to reduce unnecessary oscillation caused by friction force

FRICTION IS UNDERVALUED IN CAE ANALYSIS !





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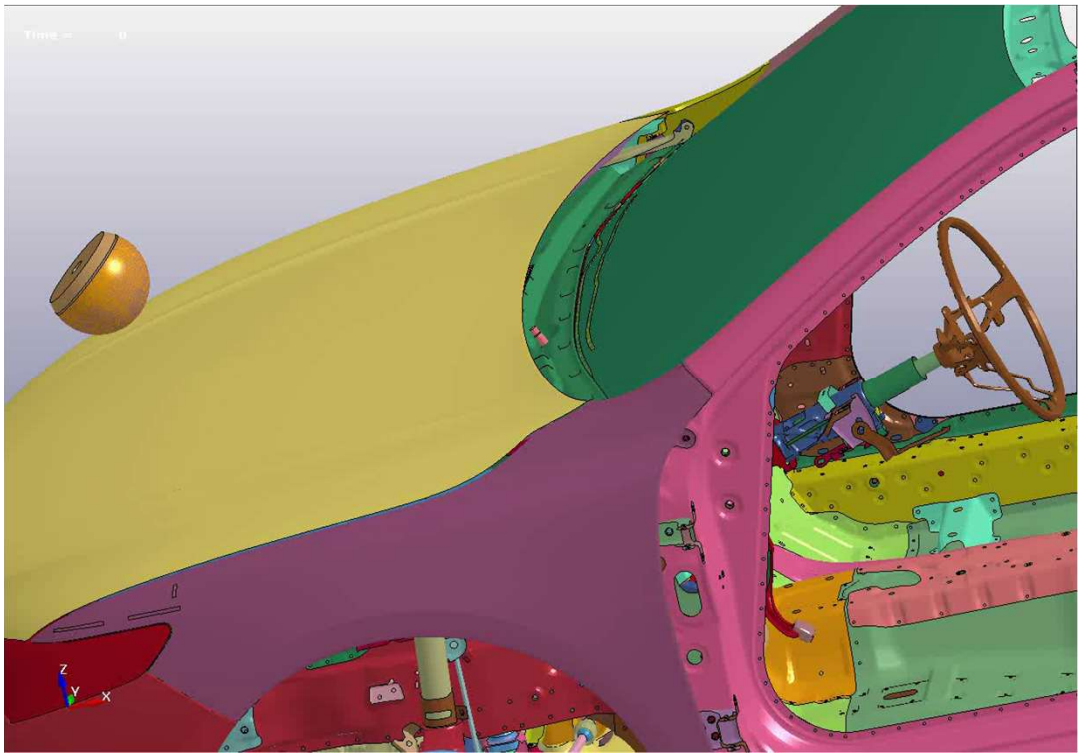
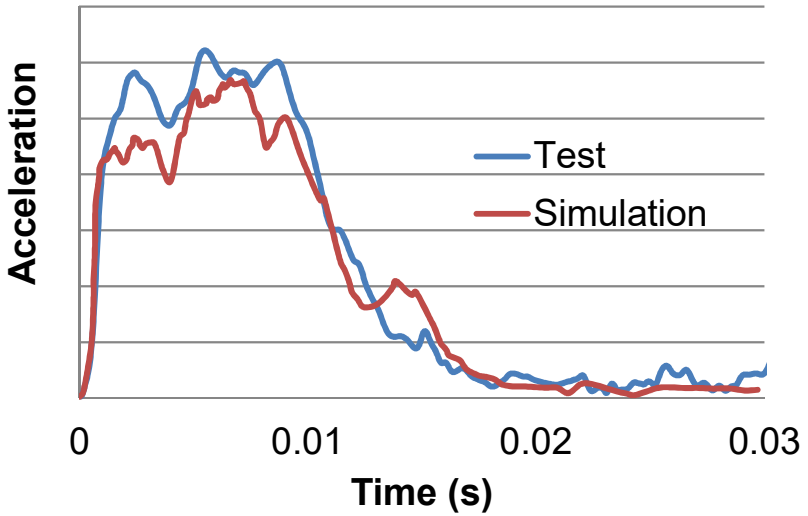
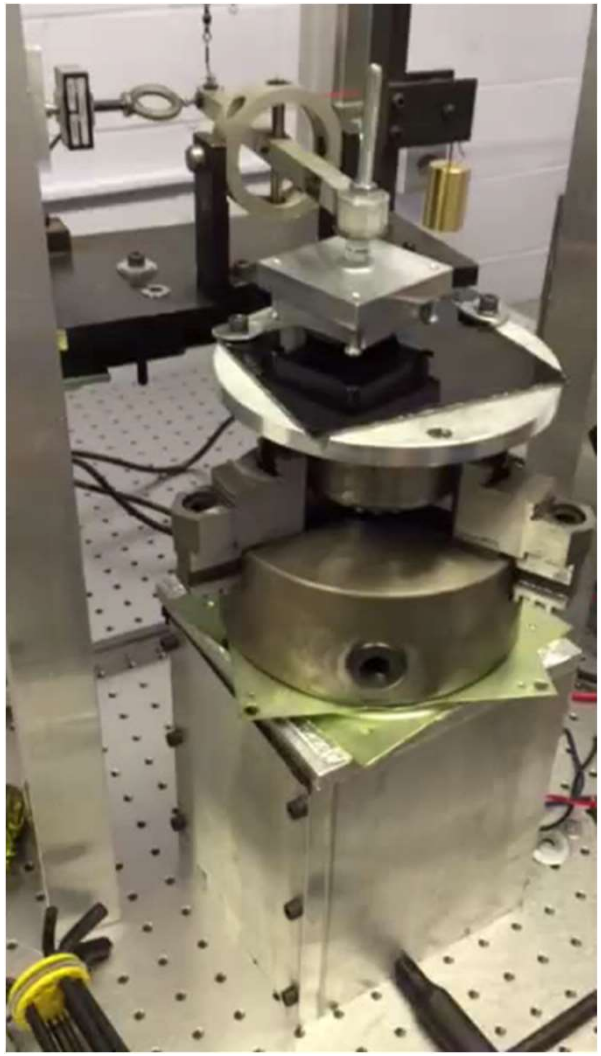
HEADFORM-TO-HOOD IMPACT MODEL

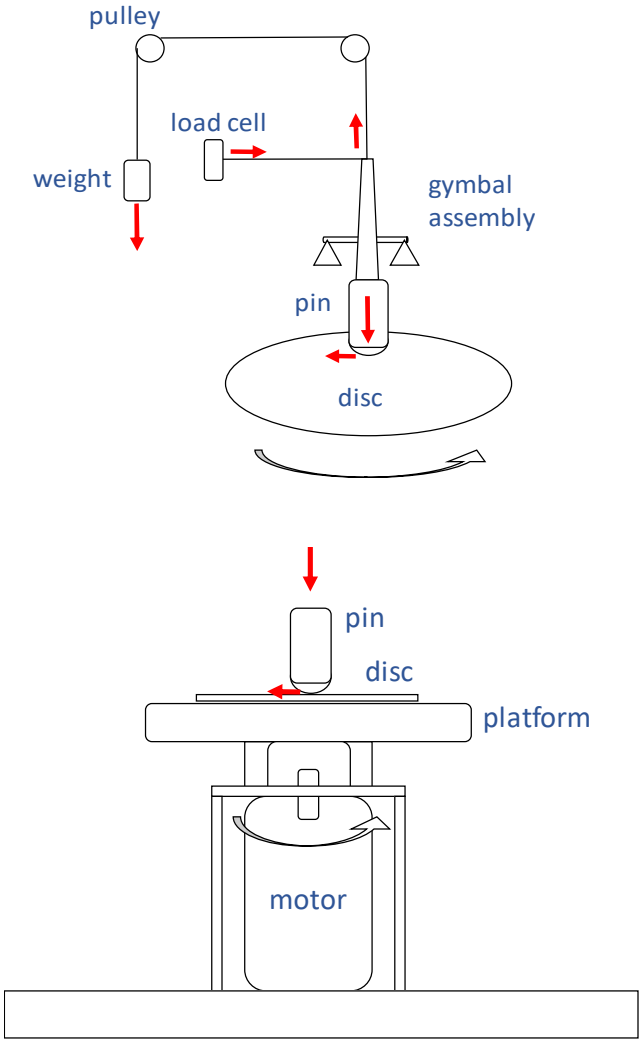




Textbook value: 0.1

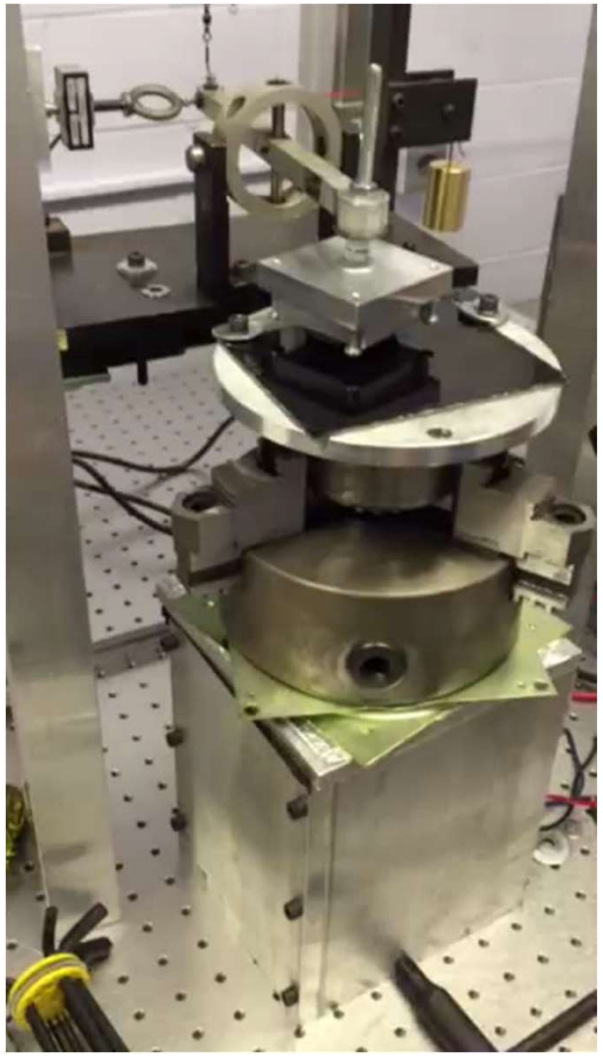
PIN-ON-DISC TRIBOMETER

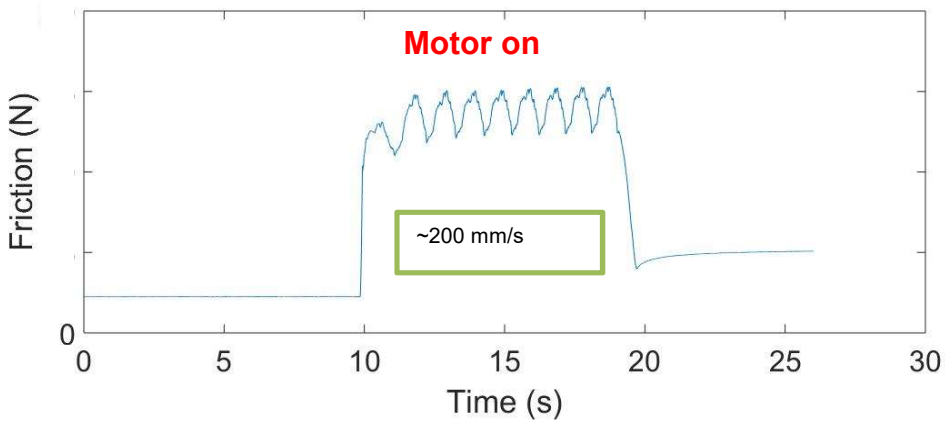


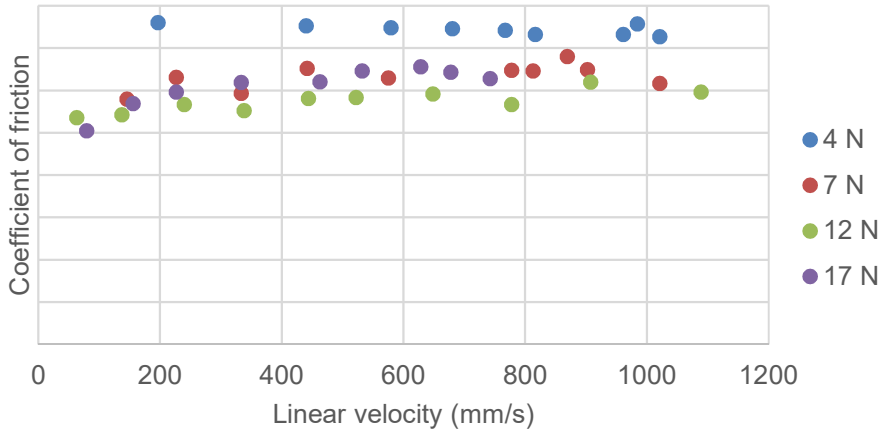


Acknowledgement:
Prof. Marcelo Dapino (Smart Materials and Structures Lab)

PIN-ON-DISC TRIBOMETER



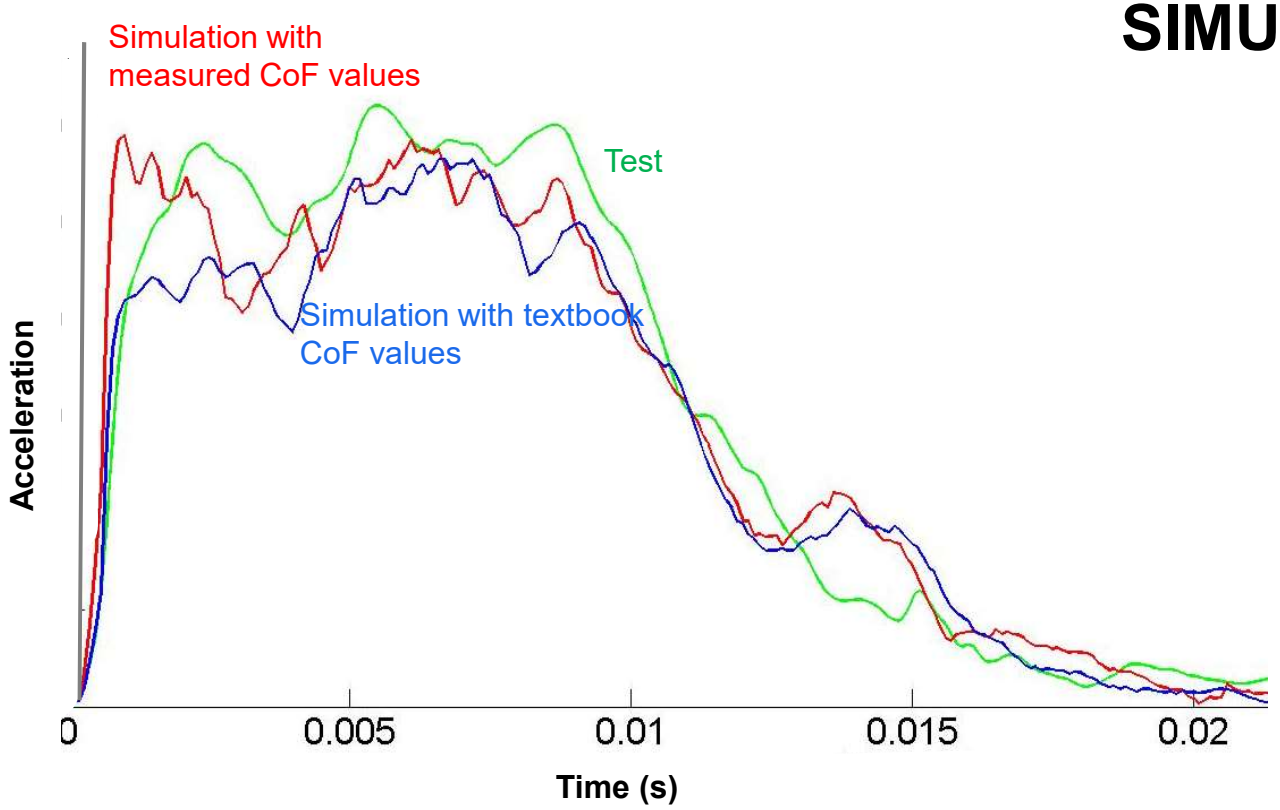




Normalized coefficient from textbook value 0.1 to approximately 1 as measured values

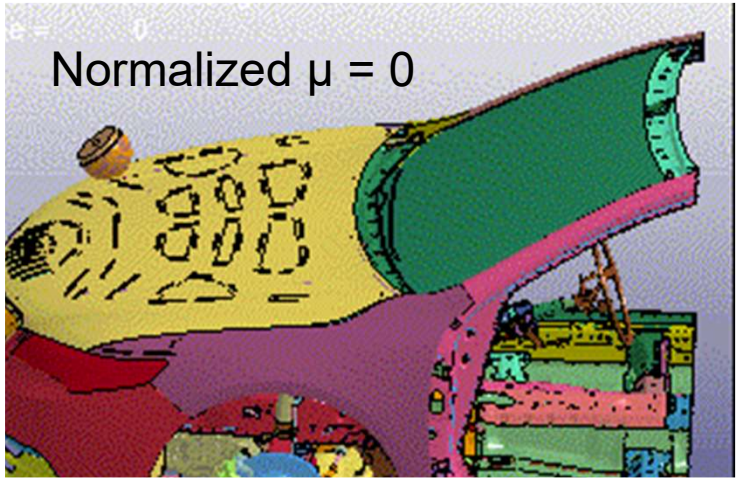
Acknowledgement:
Prof. Marcelo Dapino (Smart Materials and Structures Lab)

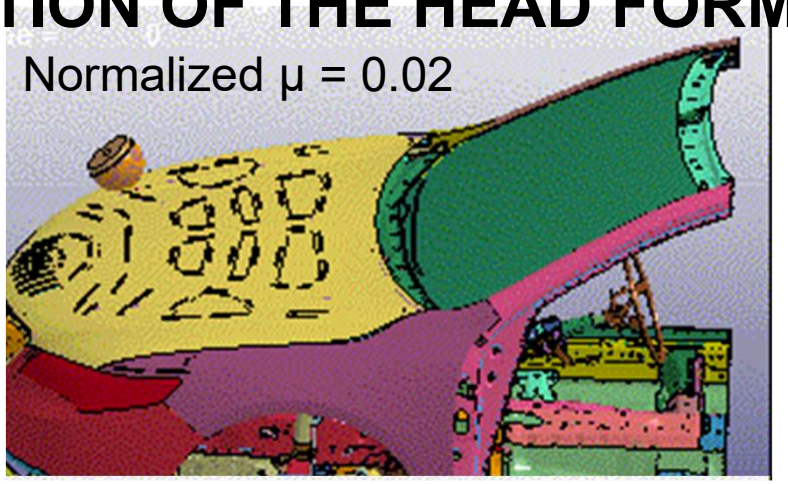
SIMULATION RESULTS

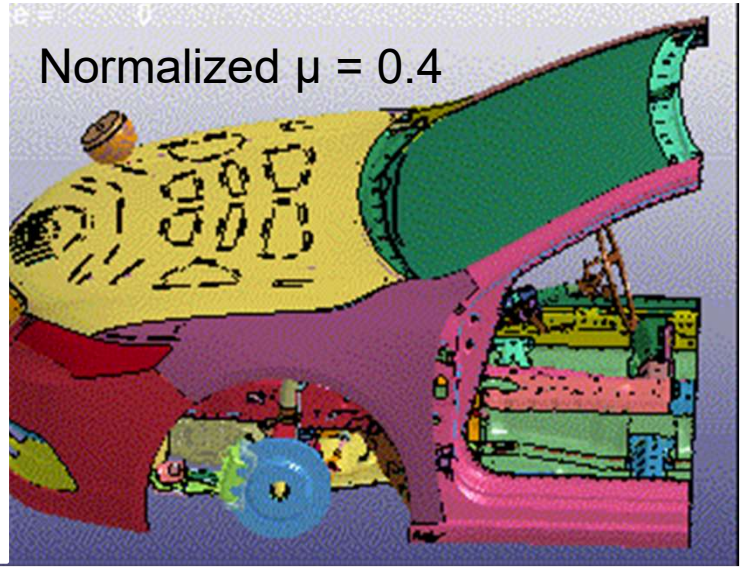


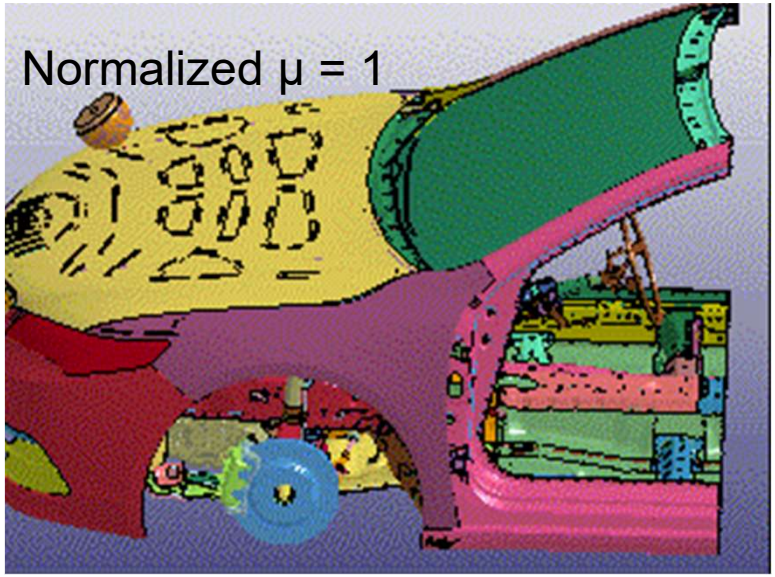
- Simulation with measured CoF values increases the magnitude of the first peak of the acceleration to match the test data
- Simulation with measured CoF values increases the normalized HIC from 0.732 to 0.85. However, there is still a discrepancy between the model and test data.

MOTION OF THE HEAD FORM

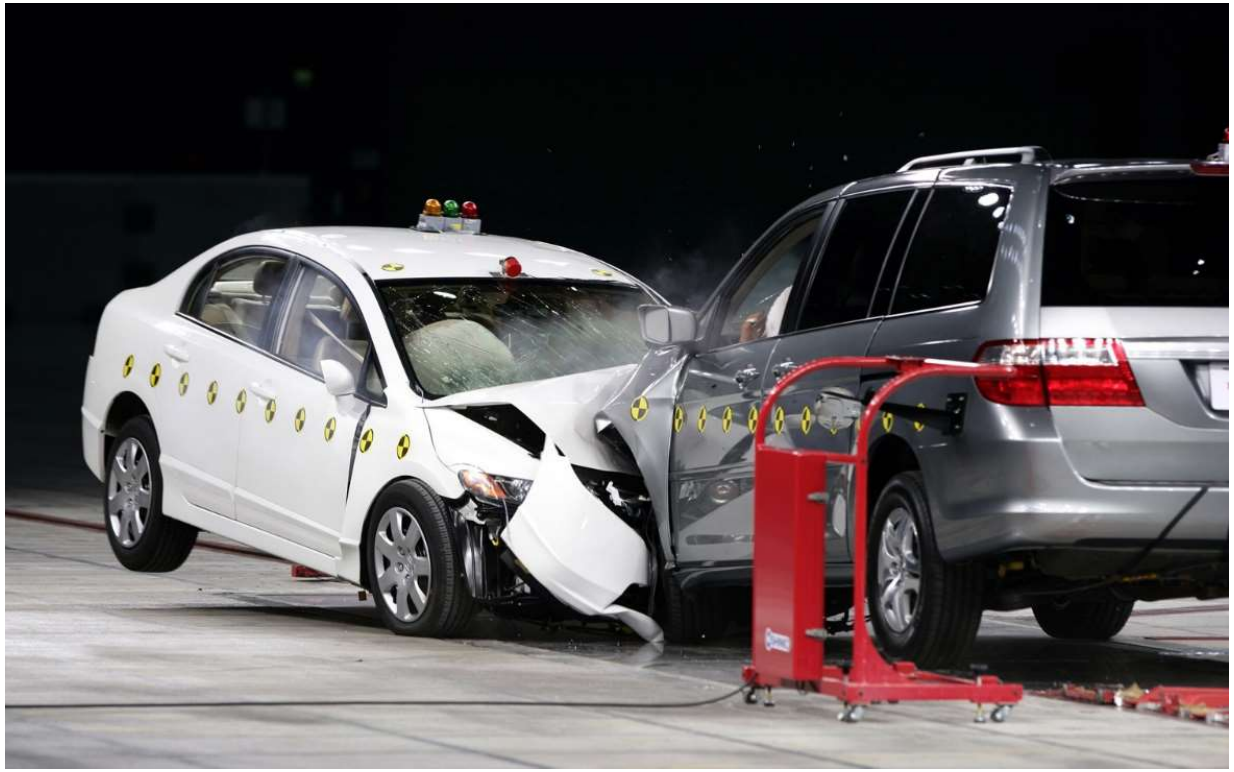






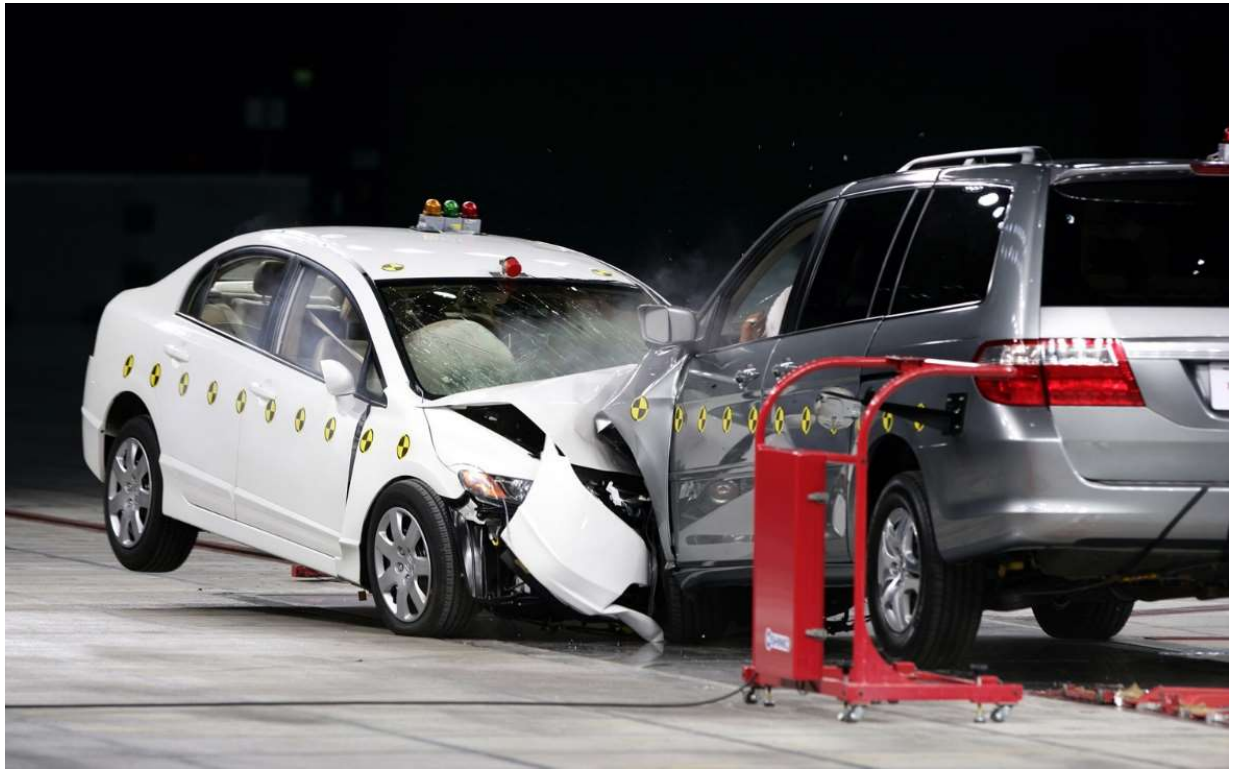


Metal to metal



https://wheels.blogs.nytimes.com

Metal to metal



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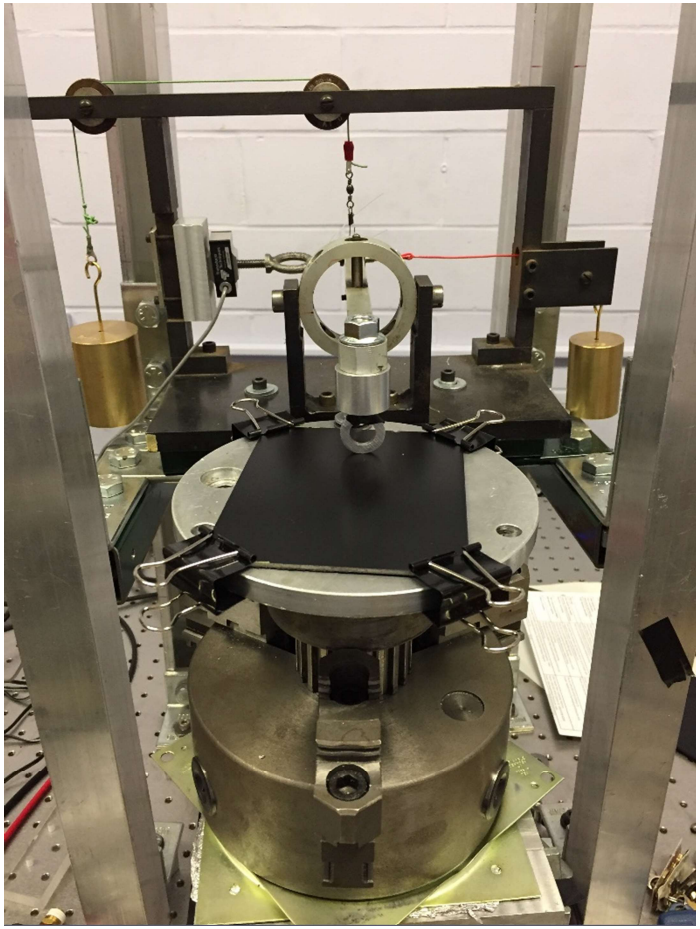
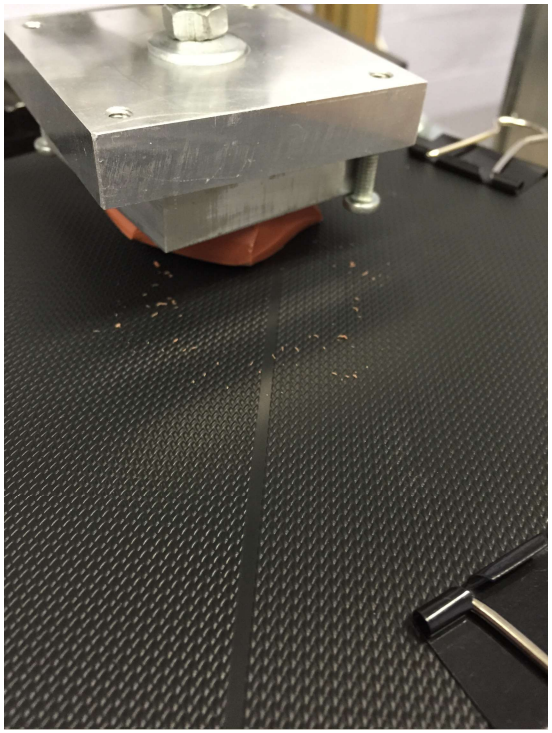
Metal to metal



FMH Rubber to plastics



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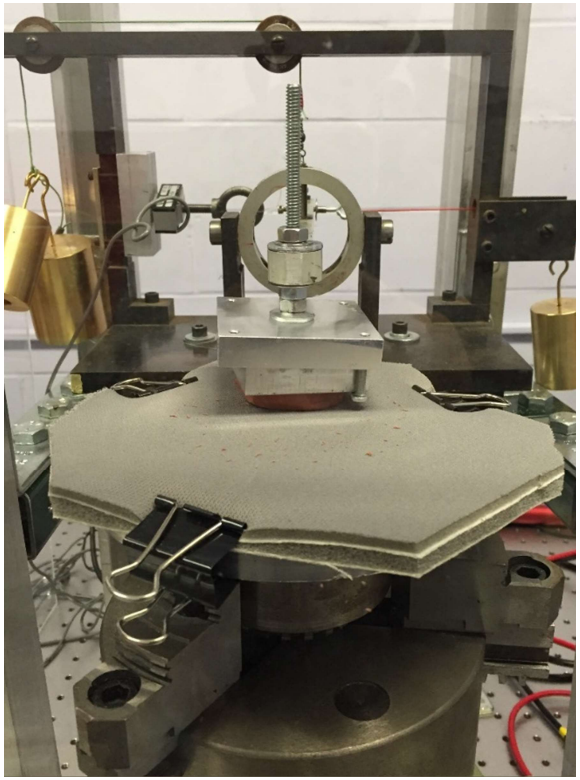
FMH rubber to roof liner



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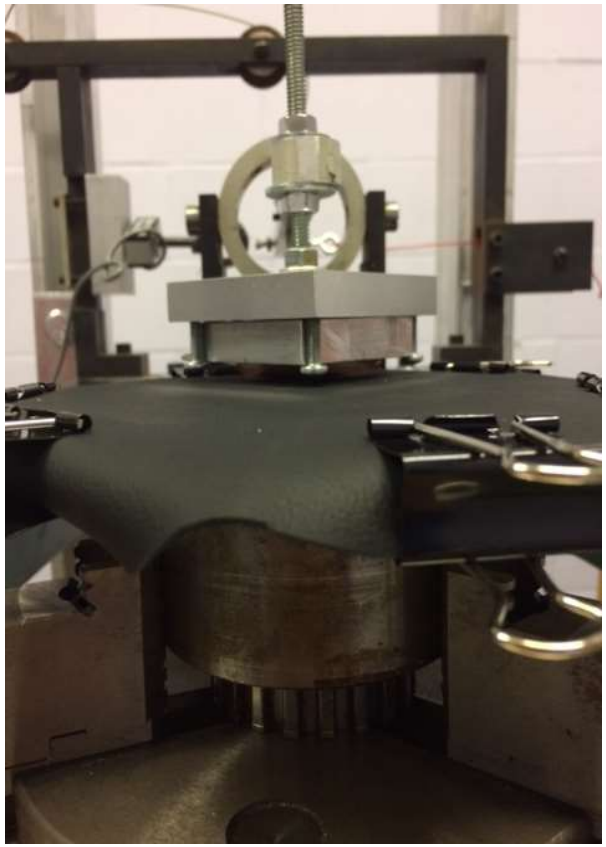
Dummy rubber vs. seat leather



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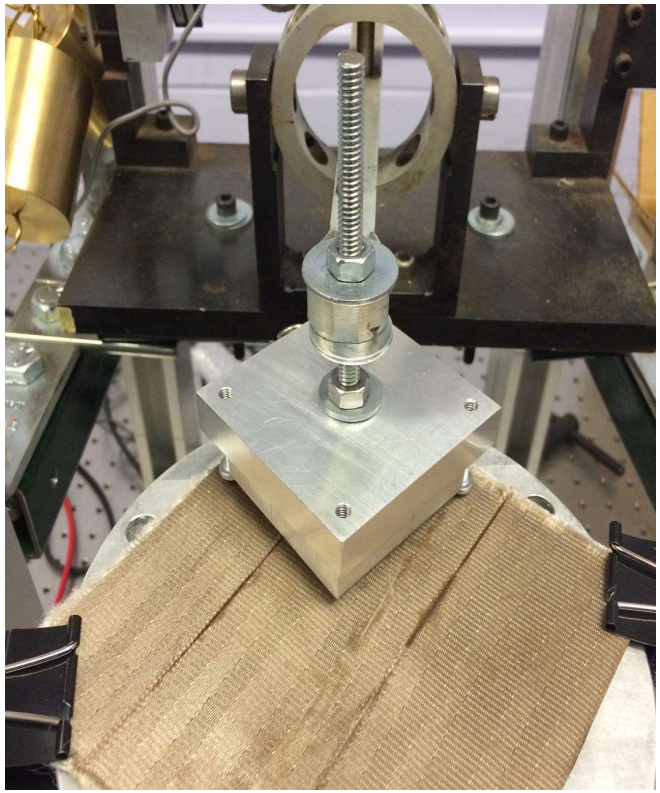
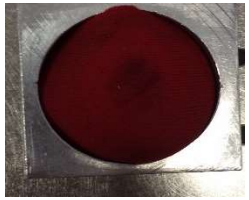
Dummy clothes fabric to seat belt



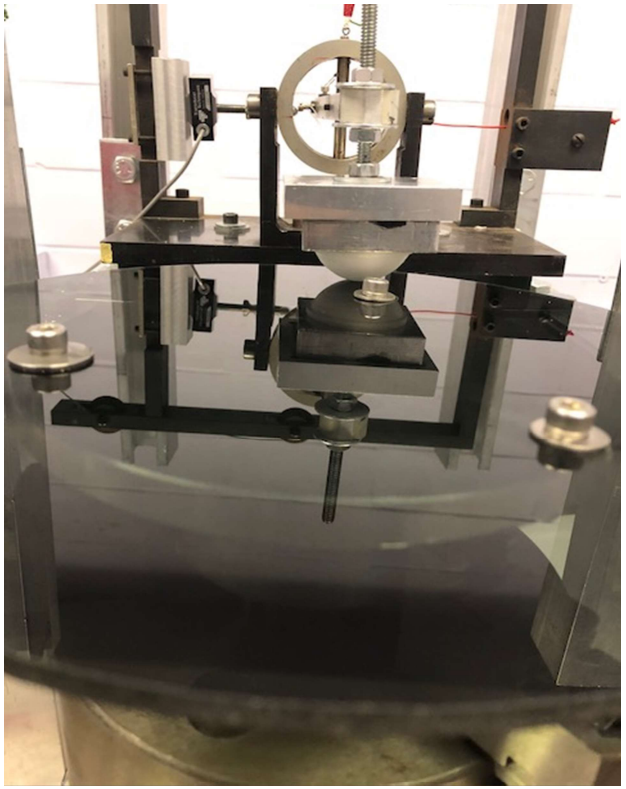


http://www.latimes.com/

Leg form to bumper

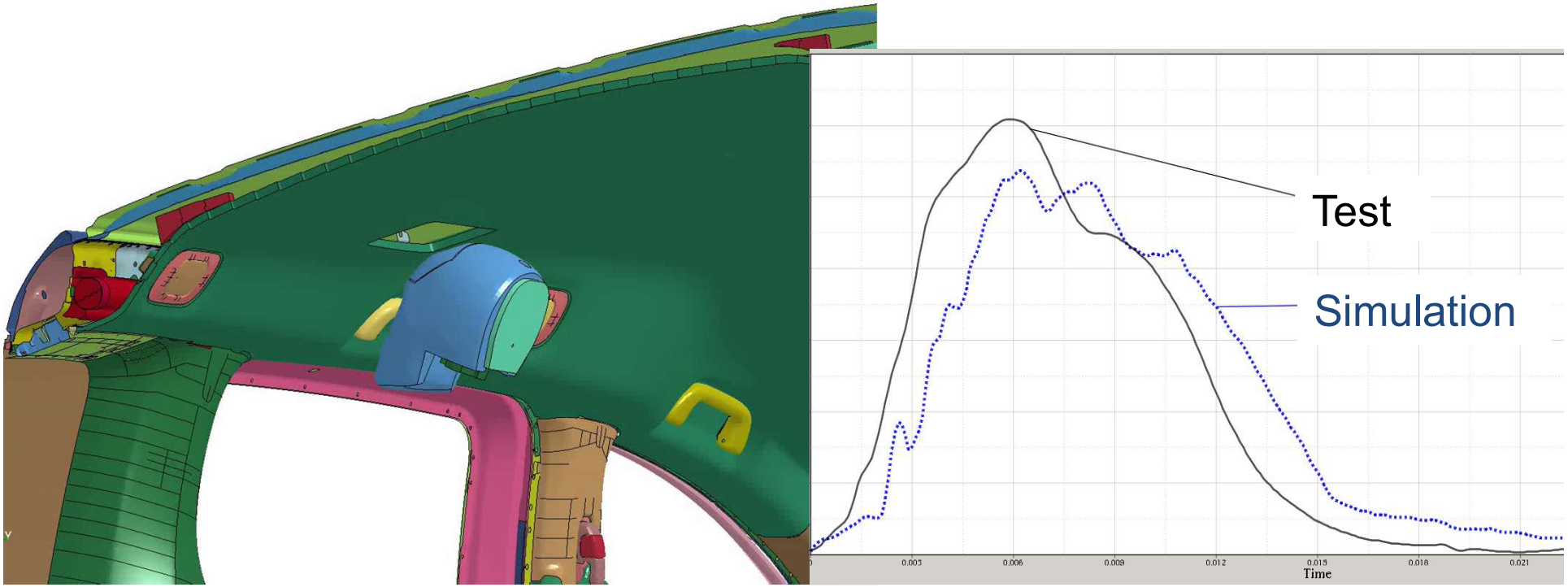
http://world.honda.com/news

Windshield glass to airbag

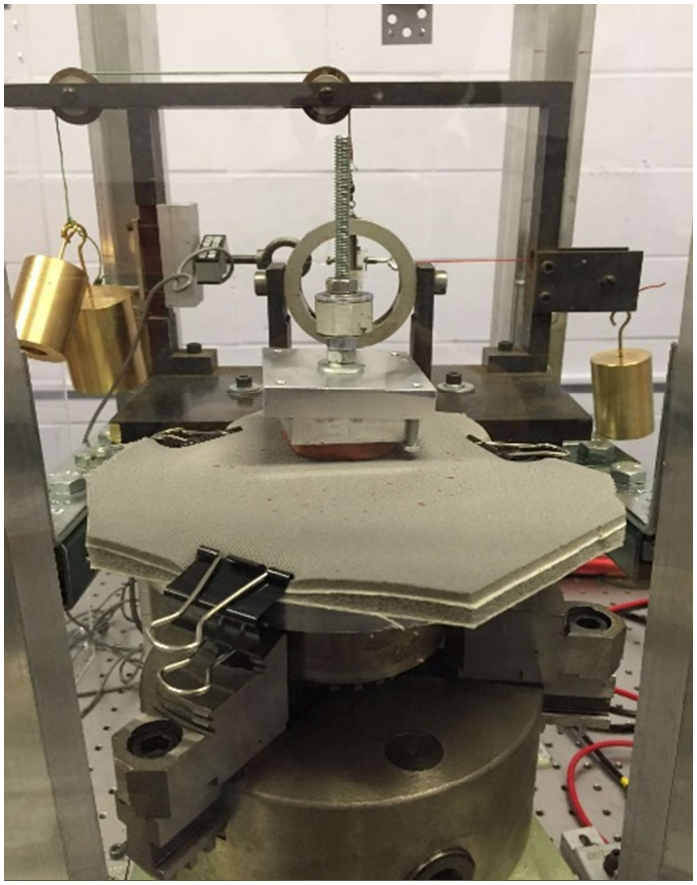


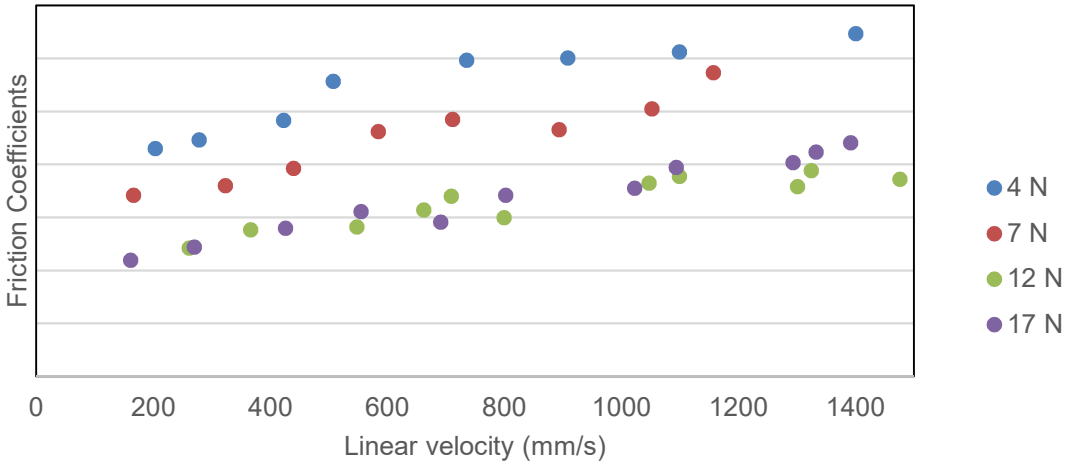
http://www.latimes.com/

IMPACT ON ROOF LINER



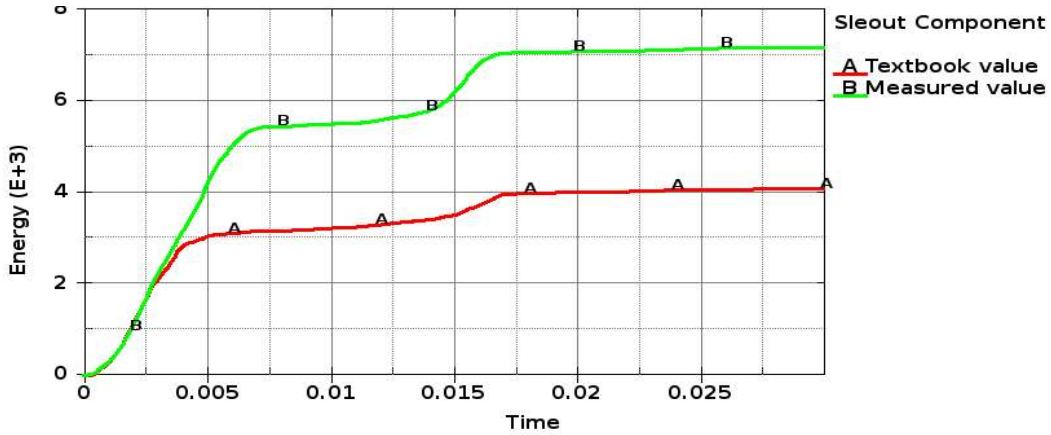
FRICTION MEASUREMENT



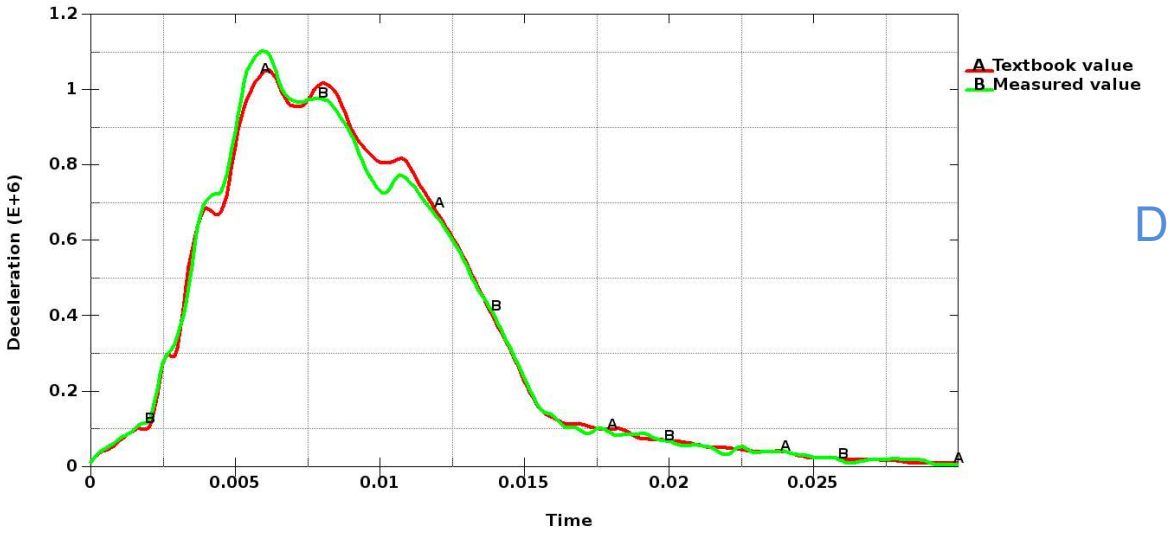


Coefficient from normalized textbook value 0.5 to approximately 1 as measured values

COMPARISON BETWEEN TEXTBOOK VALUE AND MEASURED VALUE

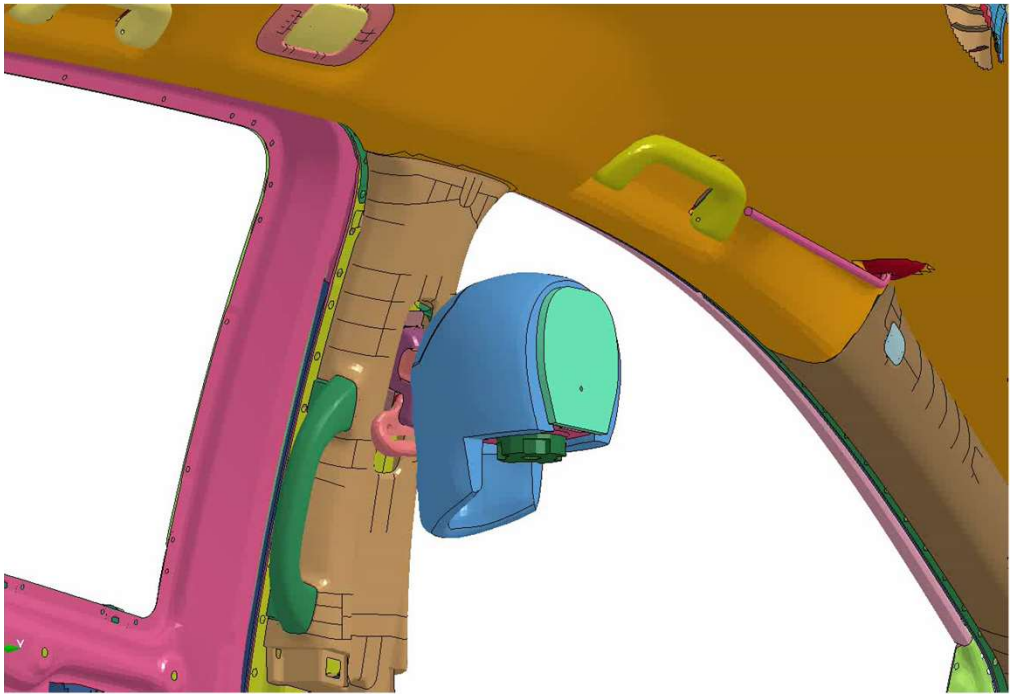


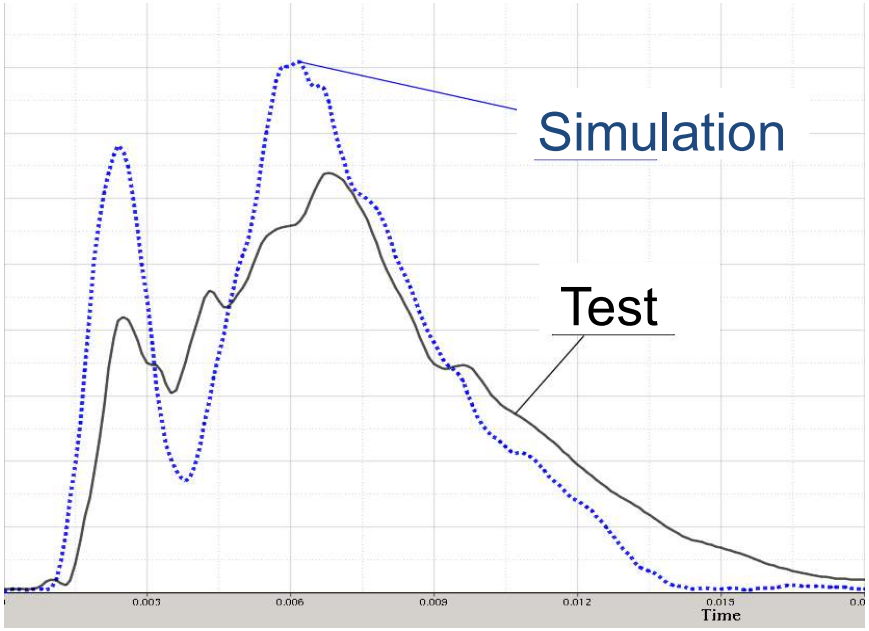
Frictional energy



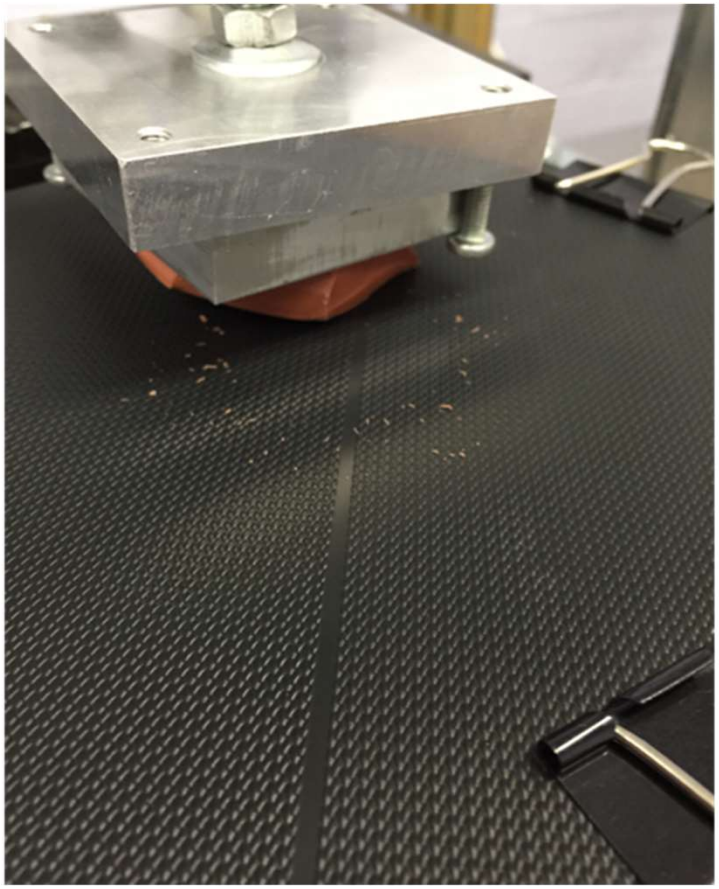
Deceleration curve

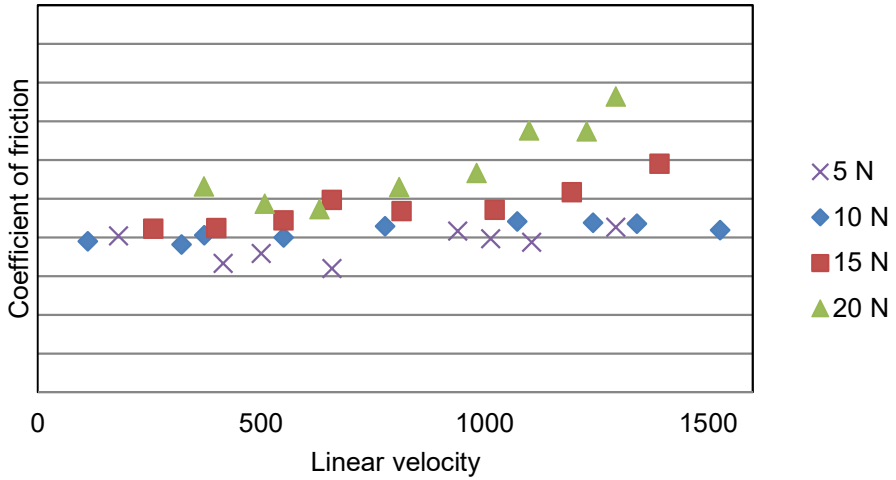
IMPACT ON B PILLAR





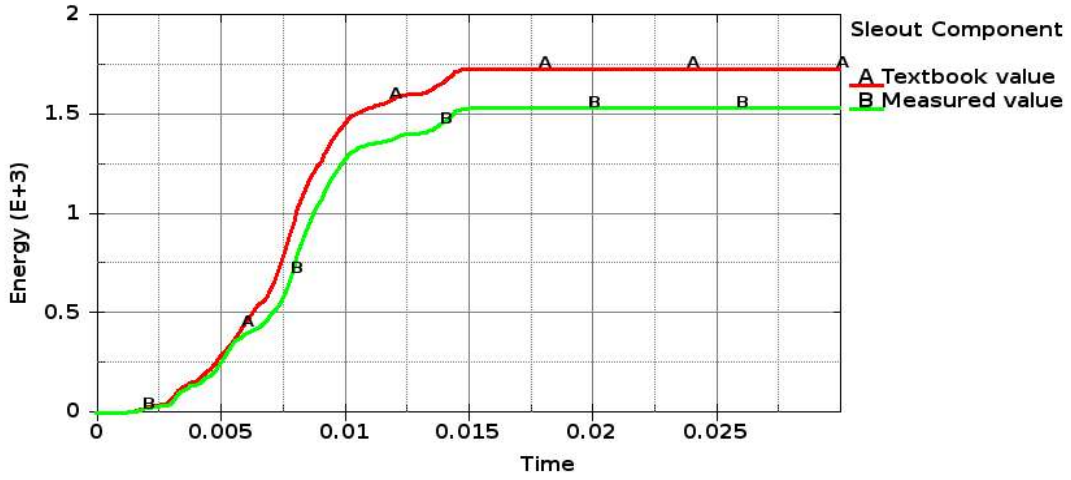
FRICTION MEASUREMENT



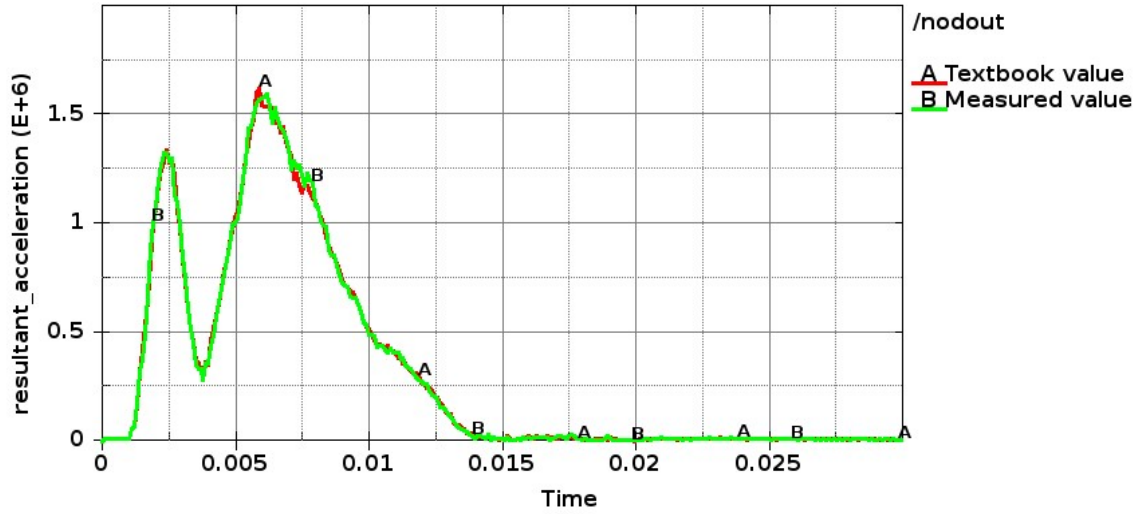


Coefficient from normalized textbook value 1
To approximately 0.625 as measured values

COMPARISON BETWEEN TEXTBOOK VALUE AND MEASURED VALUE

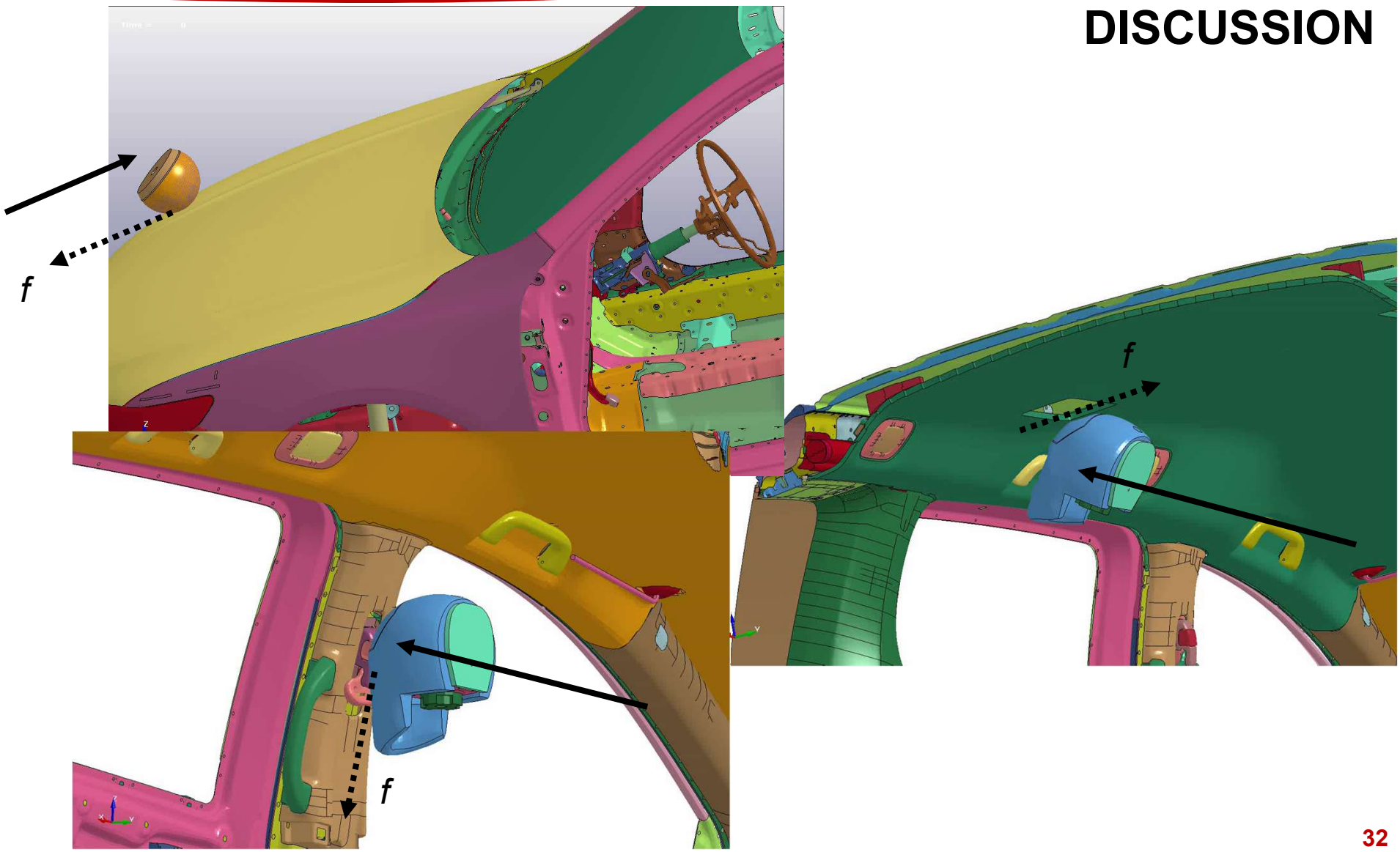


Frictional energy



Deceleration curve

DISCUSSION



CONCLUDING REMARKS

- This talk presents work in characterizing friction between materials using the pin-on-disc tribometer.
- Tests were conducted between pedestrian rubber and coated steel, ATD rubber and roof liner fabric, as well as ATD rubber and plastics.
- Measured data are then used in pedestrian-hood impact models and driver/passenger headform impact models to enhance the correlation between test and simulation.
- It is found that friction plays a bigger role when the direction of friction force is in line with the direction of the motion while friction has little influence when its direction is perpendicular to the direction of motion.
- Future work: cadaver skin testing

- Thank you!