



**THE OHIO STATE UNIVERSITY**

COLLEGE OF ENGINEERING

# CHARACTERIZATION OF FRICTION FOR HUMAN IMPACT SIMULATION IN VEHICLE CRASH APPLICATIONS

**SIMCenter**



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



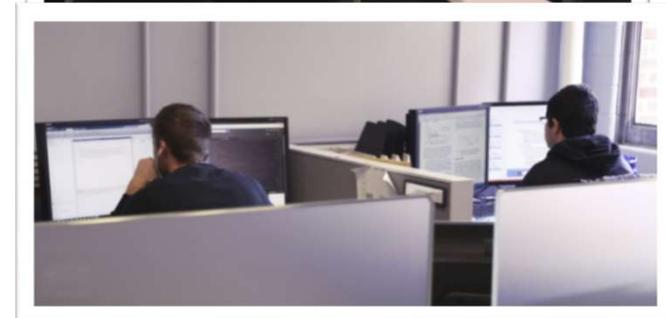
# COLUMBUS, OHIO, USA





## Simulation Innovation Modeling Center

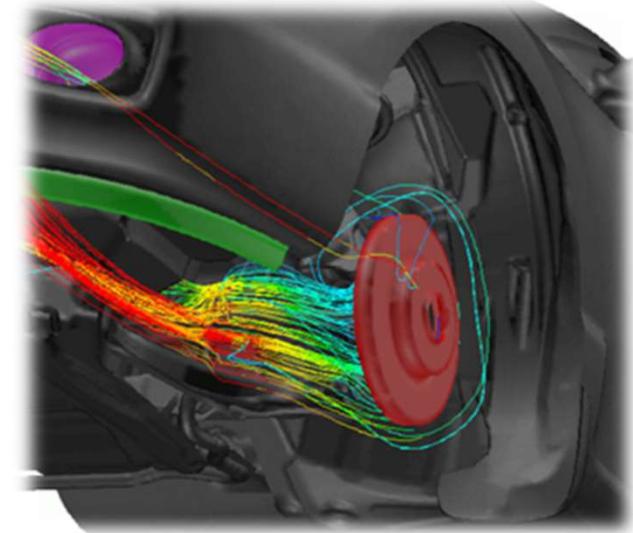
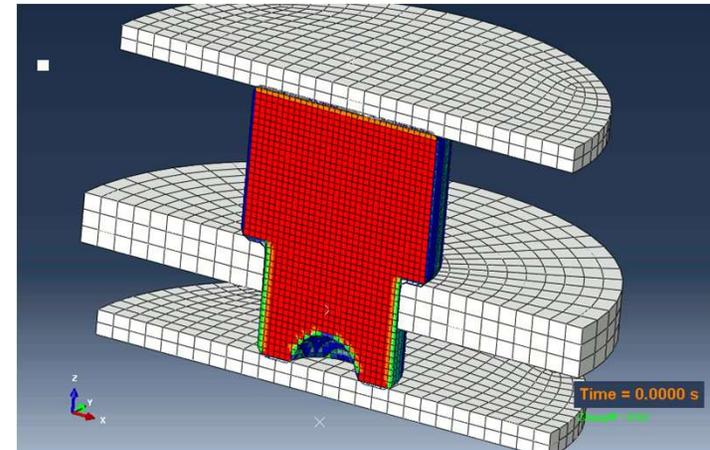
- Mission:
  - To advance computer-aided engineering techniques for Research, Design, and Manufacturing in industry
  - Main focus is on transportation
- Status:
  - Initial facilities renovation completed 2/10/2014
  - \$5 million in seed money from Honda with match from OSU
  - 2<sup>nd</sup> expansion 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

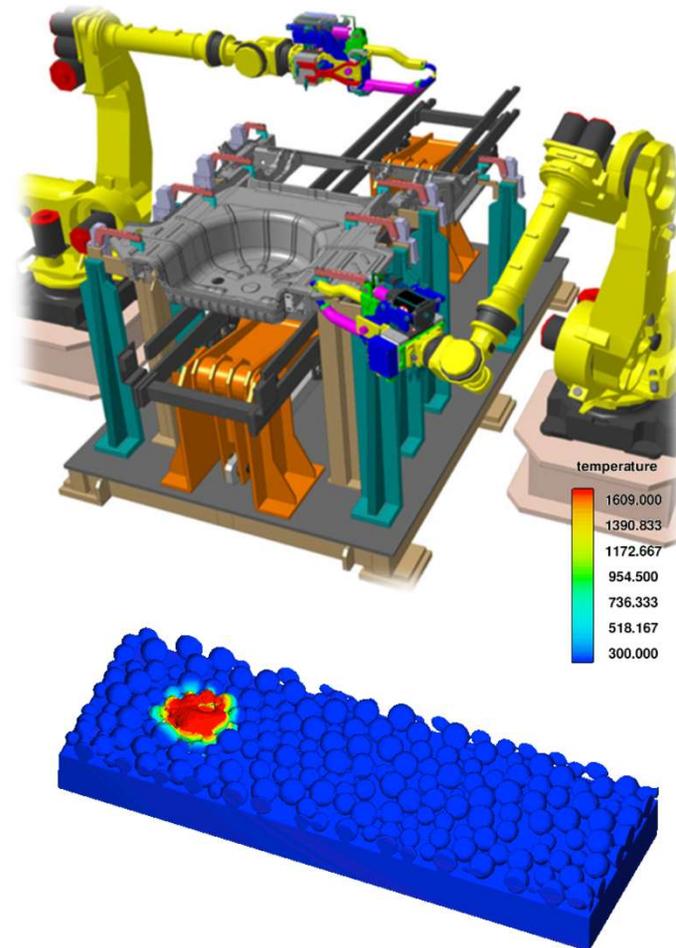
- Computational Solid and Structural Mechanics
  - Modeling of mechanical systems of complex geometries and joining techniques under linear and non-linear deformation
- Computational Fluid Mechanics
  - Accurate performance prediction of steady-state and time-dependent external, internal flows, and acoustics
- 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





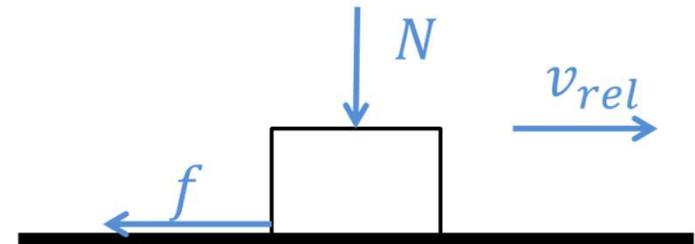
## OUTLINE

- 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



## FRICITION

- 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

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

where  $\mu$  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

1976:  
DYNA3D®

1986:  
Interface friction  
DYNA3D®

1990:  
Rigidwall Coulumb friction  
LS-DYNA®

1992:  
Coulumb friction for contacts  
LS-DYNA®

1997:  
Friction curves of contacts  
LS-DYNA®



# DEFINE FRICTION IN CONTACTS

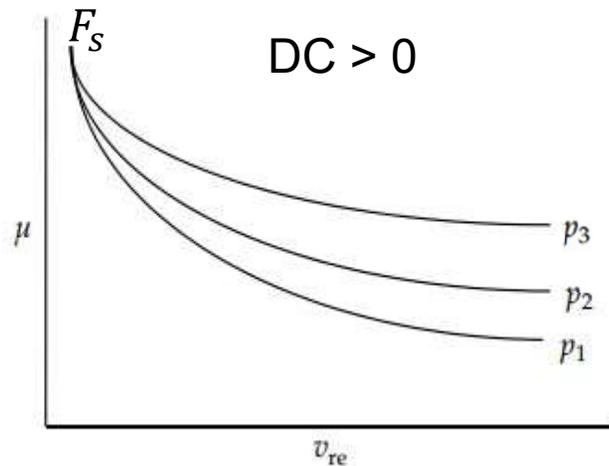
\*CONTACT

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

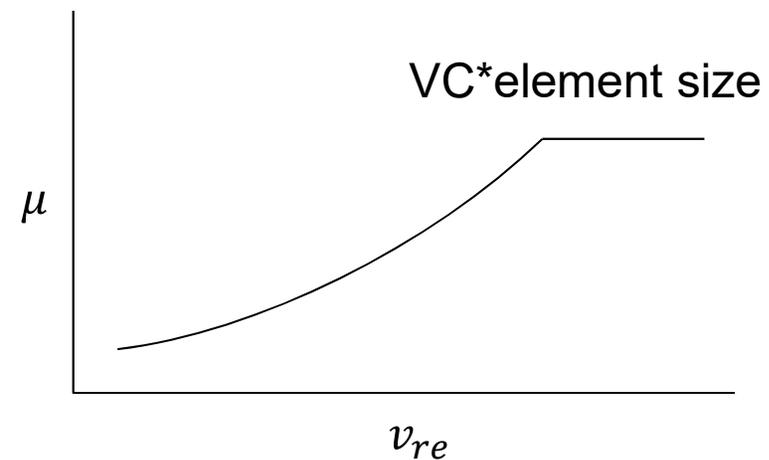
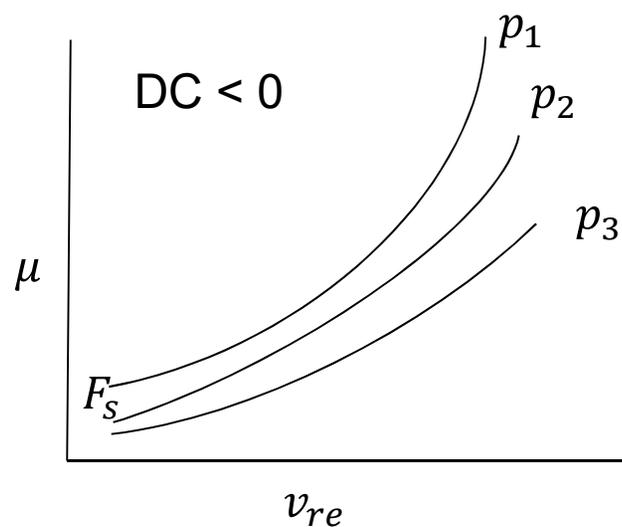
The screenshot shows the 'Keyword Input Form' for defining contact parameters. The form is titled '\*CONTACT\_SINGLE\_SURFACE\_(ID/TITLE/MPP) ( 1 )'. It contains several input fields and buttons. The 'SSID' field is circled in red, and the 'MSID' field is also circled in red. The 'FS' field is highlighted with a red box. The 'FD' field is also highlighted with a red box. The 'DC' field is highlighted with a red box. The 'VC' field is highlighted with a red box. The 'VDC' field is highlighted with a red box. The 'PENCHK' field is highlighted with a red box. The 'BT' field is highlighted with a red box. The 'DT' field is highlighted with a red box. The 'FS' field contains the value 0.0800000. The 'FD' field contains the value 0.0800000. The 'DC' field contains the value 0.0. The 'VC' field contains the value 177.00000. The 'VDC' field contains the value 20.000000. The 'PENCHK' field contains the value 0. The 'BT' field contains the value 0.0. The 'DT' field contains the value 1.000e+20. The 'SSID' field contains the value 9000. The 'MSID' field contains the value 0. The 'SSTYP' field contains the value 2. The 'MSTYP' field contains the value 2. The 'SBOXID' field contains the value 0. The 'MBOXID' field contains the value 0. The 'SPR' field contains the value 0. The 'MPR' field contains the value 0. The 'IGNORE' field contains the value 0. The 'BUCKET' field contains the value 200. The 'LCBUCKET' field is empty. The 'NS2TRACK' field contains the value 0. The 'INITITER' field contains the value 2. The 'PARMAX' field contains the value 1.0005. The 'UNUSED' field is empty. The 'CPARM6' field contains the value 0. The 'CHKSEGS' field is empty. The 'PENSE' field contains the value 1.0. The 'GRPABLE' field contains the value 0. The 'MPP1' and 'MPP2' checkboxes are unchecked. The 'Use \*Parameter' checkbox is unchecked. The 'NewID' and 'Draw' buttons are visible. The 'Pick', 'Add', 'Accept', 'Delete', 'Default', and 'Done' buttons are visible. The '(Subsys: 2)' and 'Setting' buttons are visible. The 'Total Card: 1' 'Smallest ID: 6' 'Largest ID: 6' 'Total deleted card: 0' information is displayed at the bottom.



## FRICITION – VELOCITY CURVES



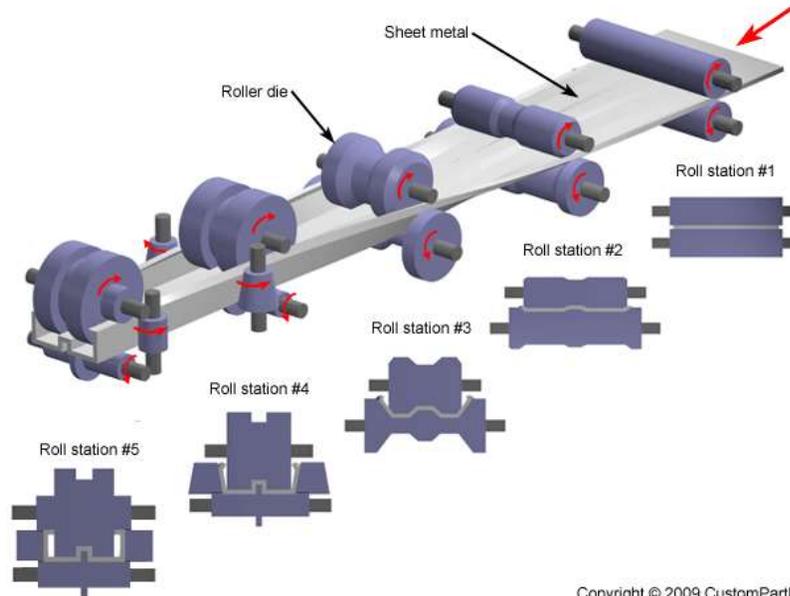
$$\mu = F_D + (F_S - F_D)e^{-DC|v_{rel}|}$$



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



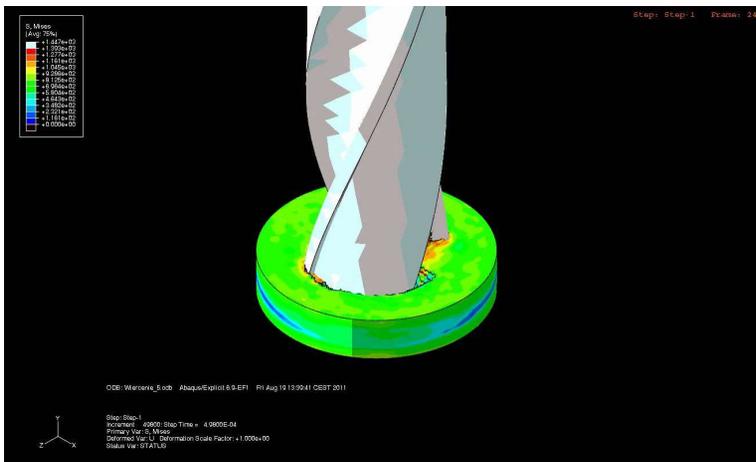
# FRICITION IS UNDERVALUED IN CAE ANALYSIS !

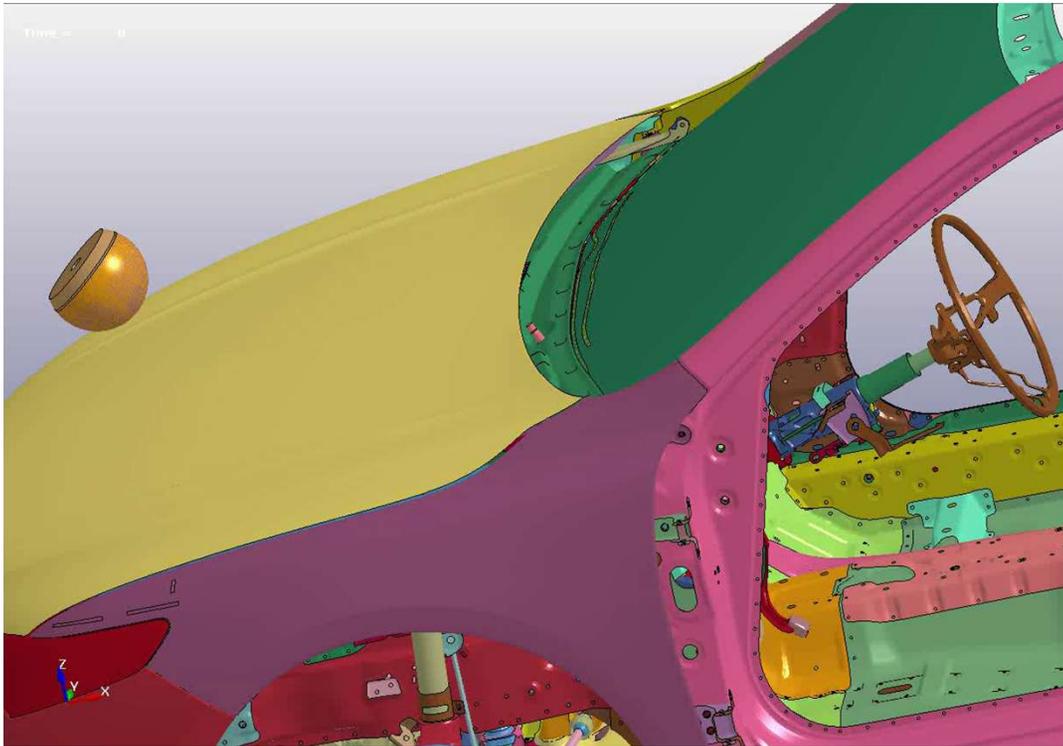


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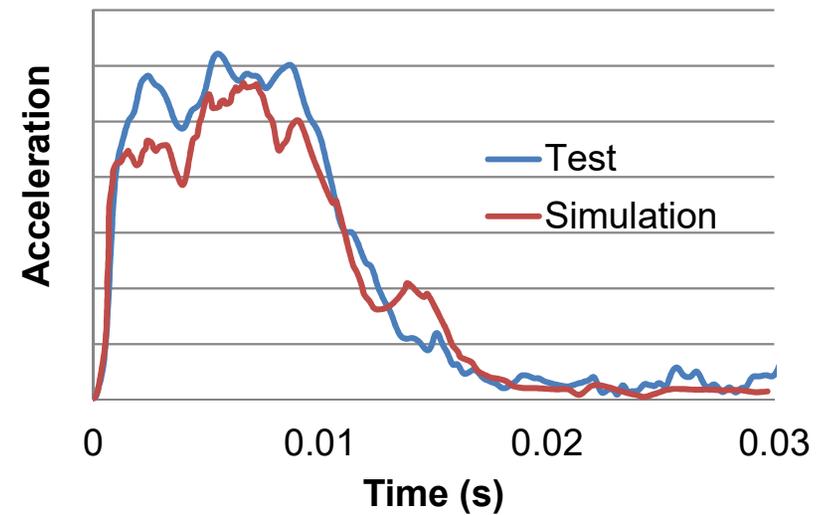


[www.iihs.org](http://www.iihs.org)





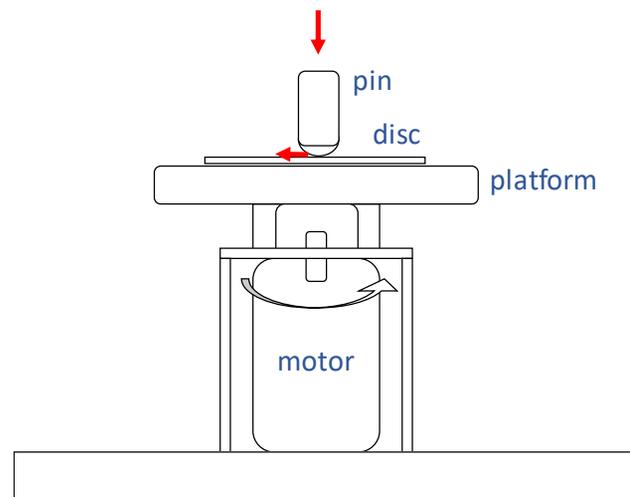
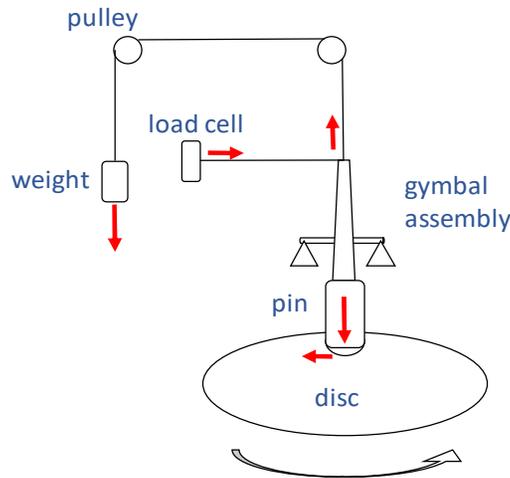
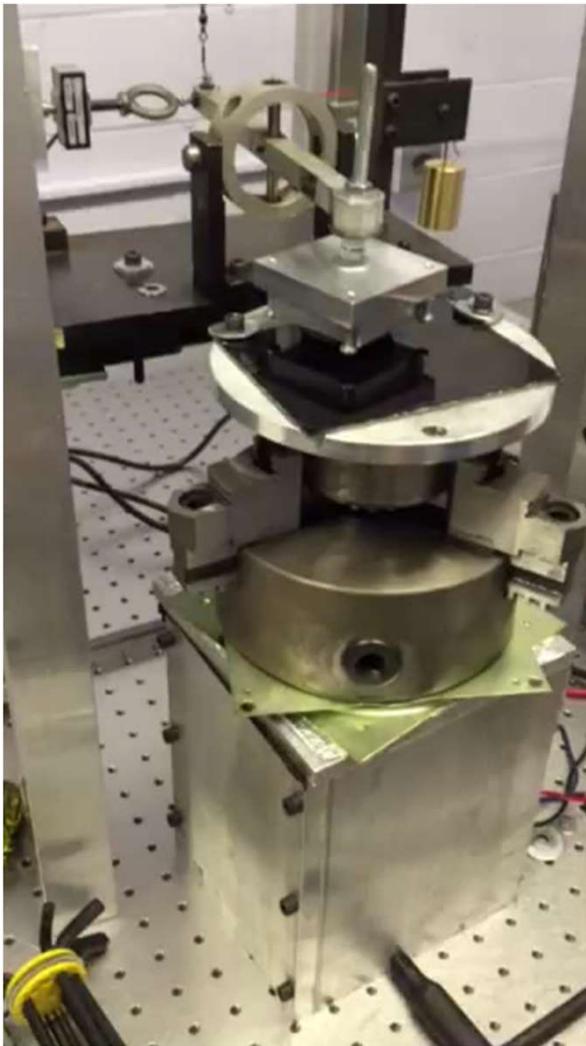
## HEADFORM-TO-HOOD IMPACT MODEL



Textbook value: 0.1



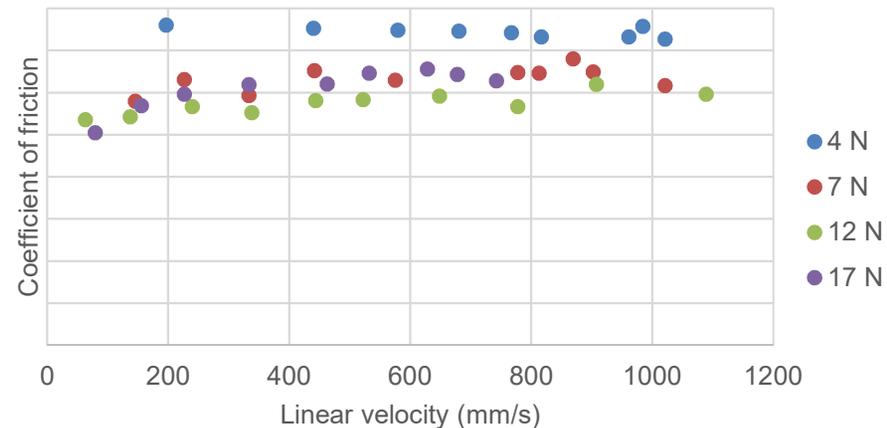
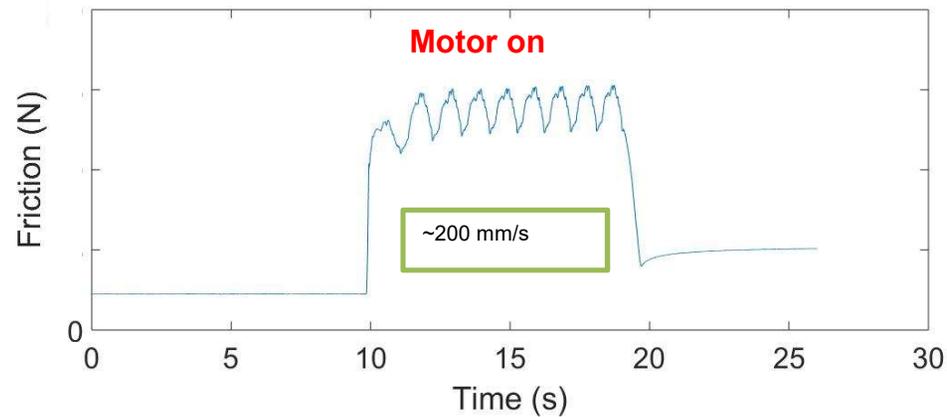
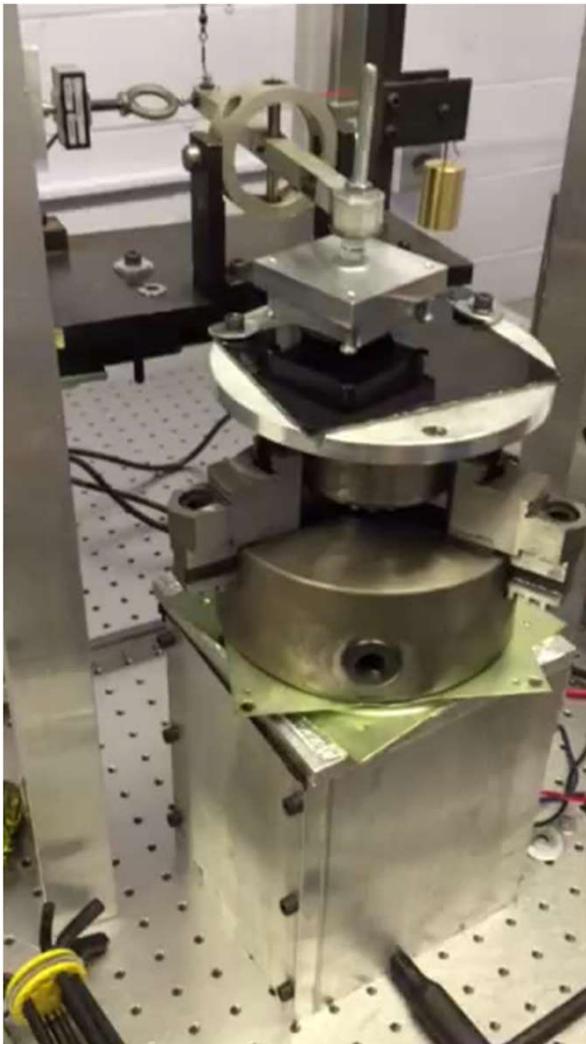
## PIN-ON-DISC TRIBOMETER



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



## PIN-ON-DISC TRIBOMETER



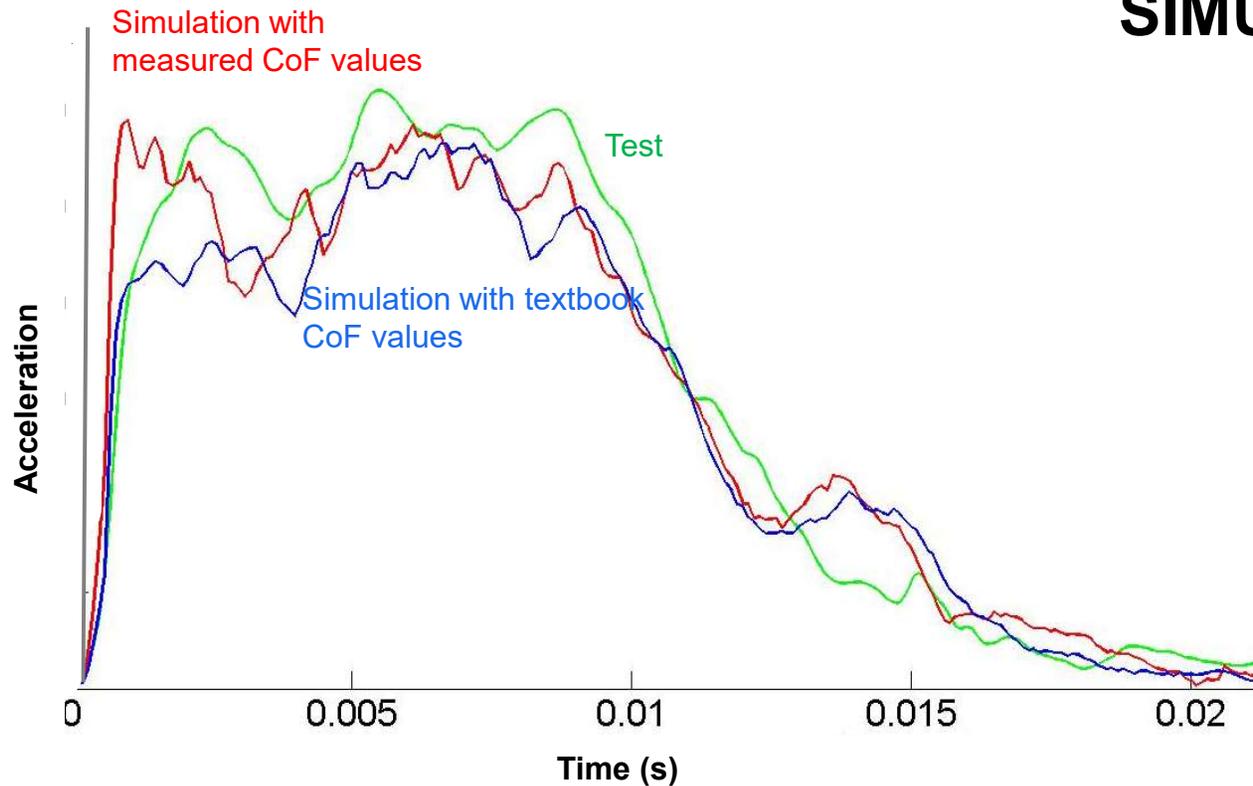
Normalized coefficient from textbook value 0.1  
to approximately 1 as measured values

Acknowledgement:

Prof. Marcelo Dapino (Smart Materials and Structures Lab)



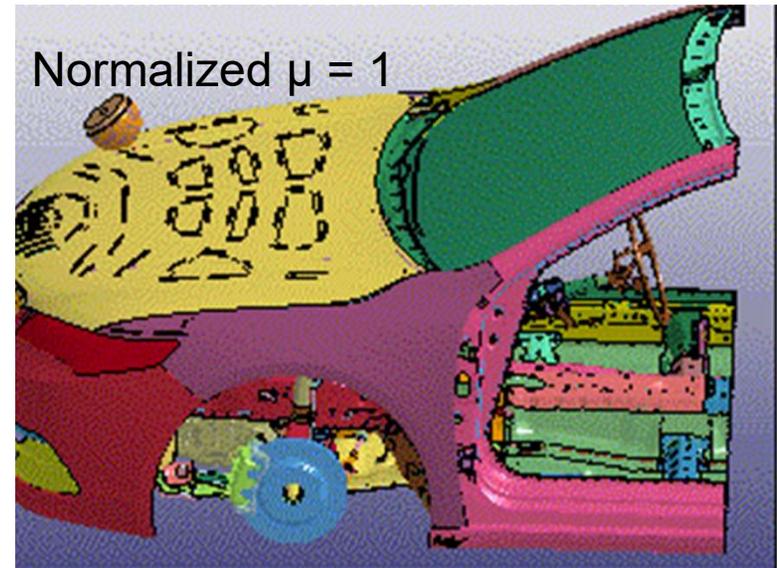
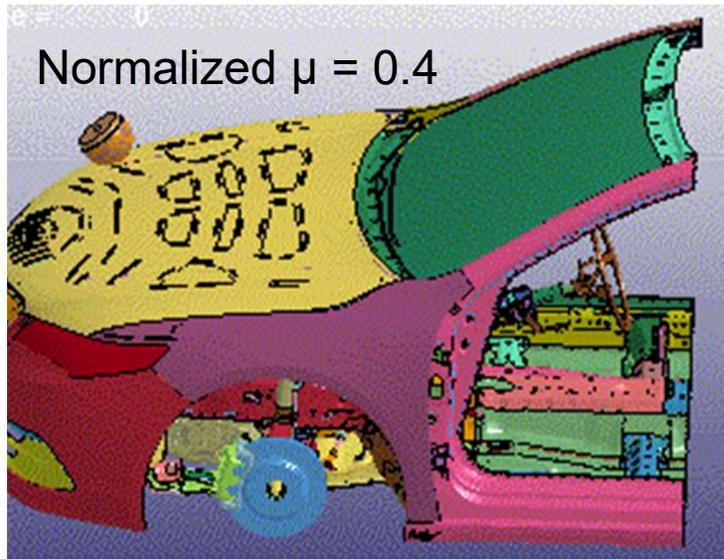
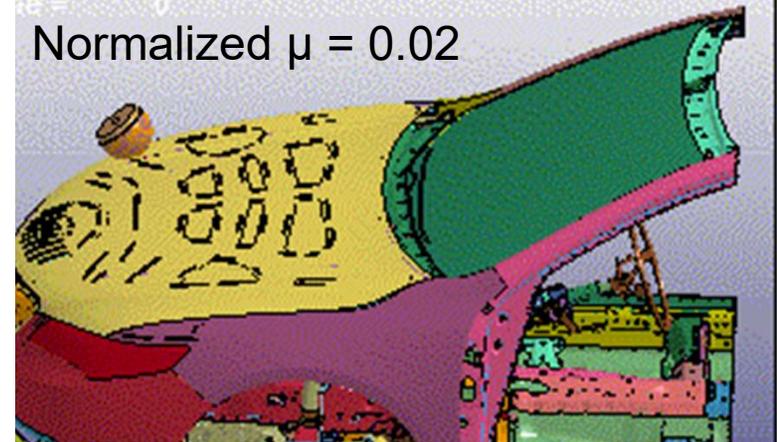
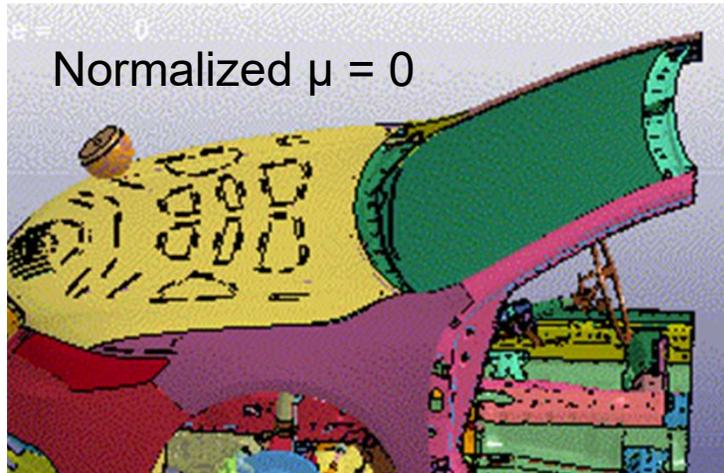
## SIMULATION RESULTS



- 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>



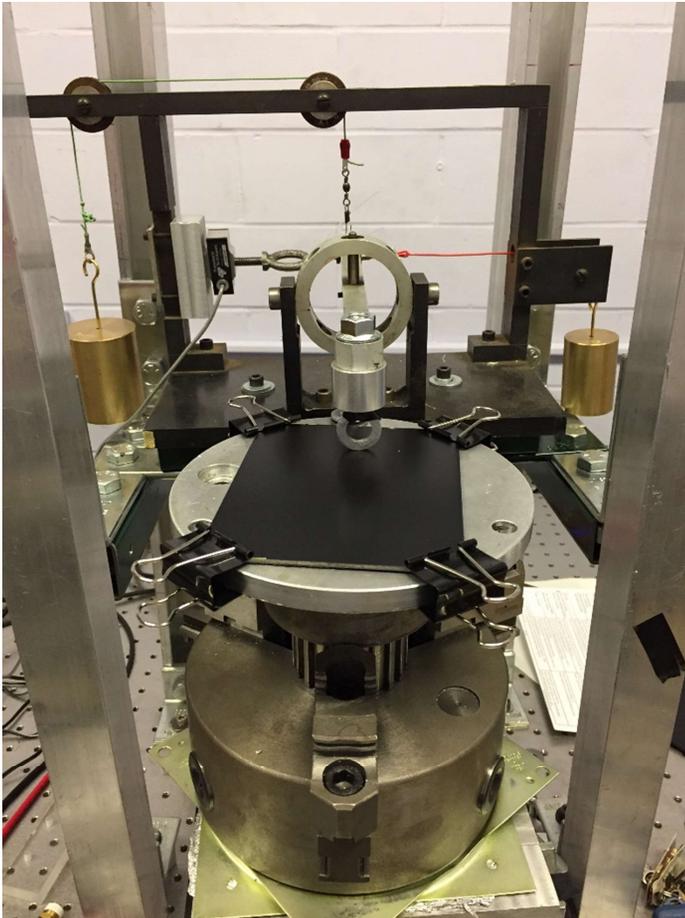
## Metal to metal



<https://wheels.blogs.nytimes.com>

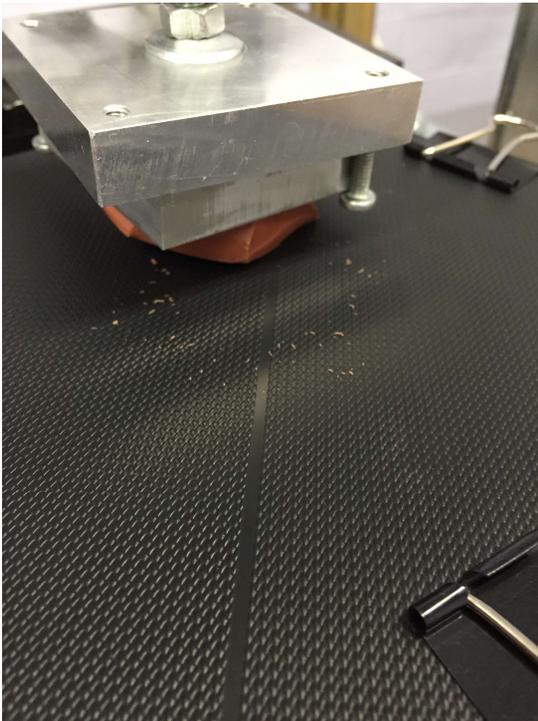


## Metal to metal





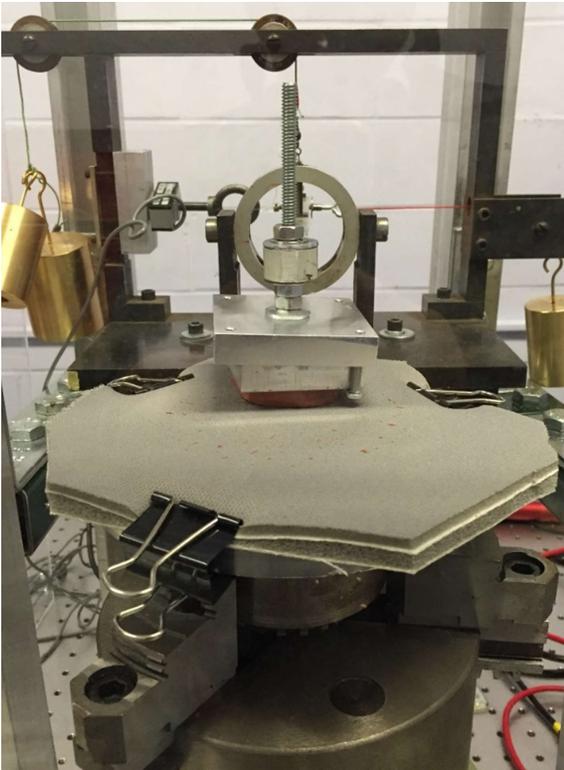
## FMH Rubber to plastics



[www.iihs.org/](http://www.iihs.org/)



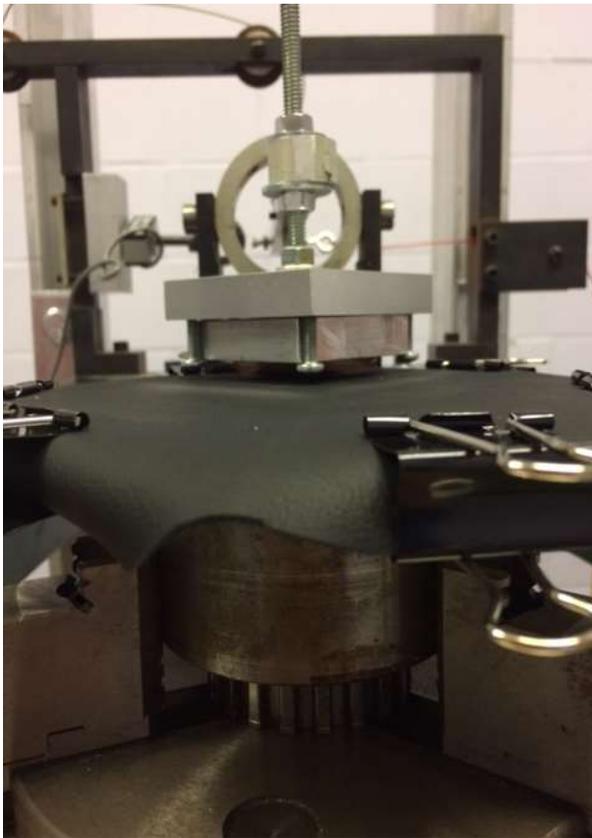
## FMH rubber to roof liner



[www.iihs.org/](http://www.iihs.org/)



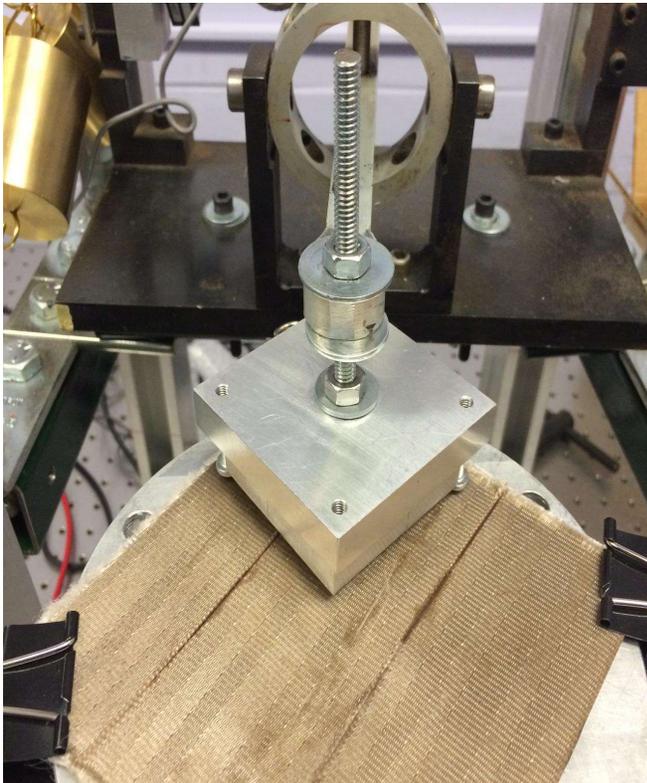
## Dummy rubber vs. seat leather



[www.iihs.org/](http://www.iihs.org/)



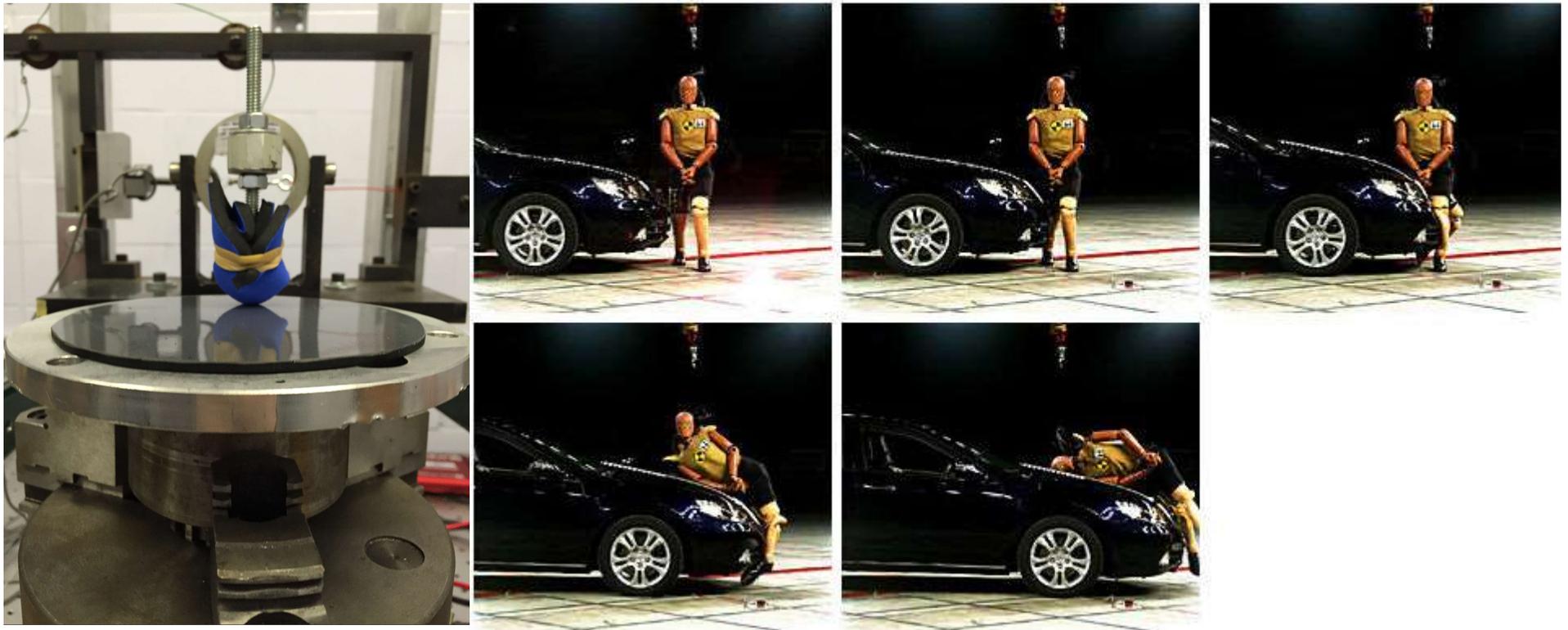
## Dummy clothes fabric to seat belt



<http://www.latimes.com/>



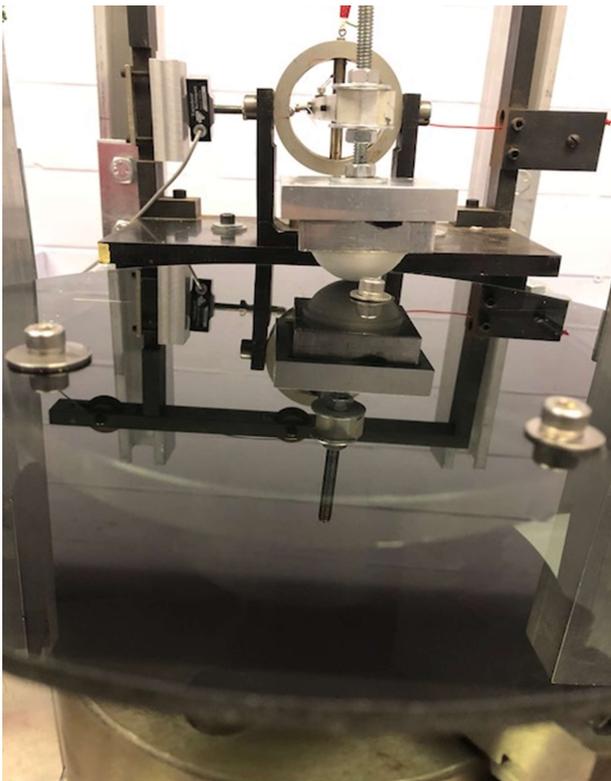
## Leg form to bumper



<http://world.honda.com/news>



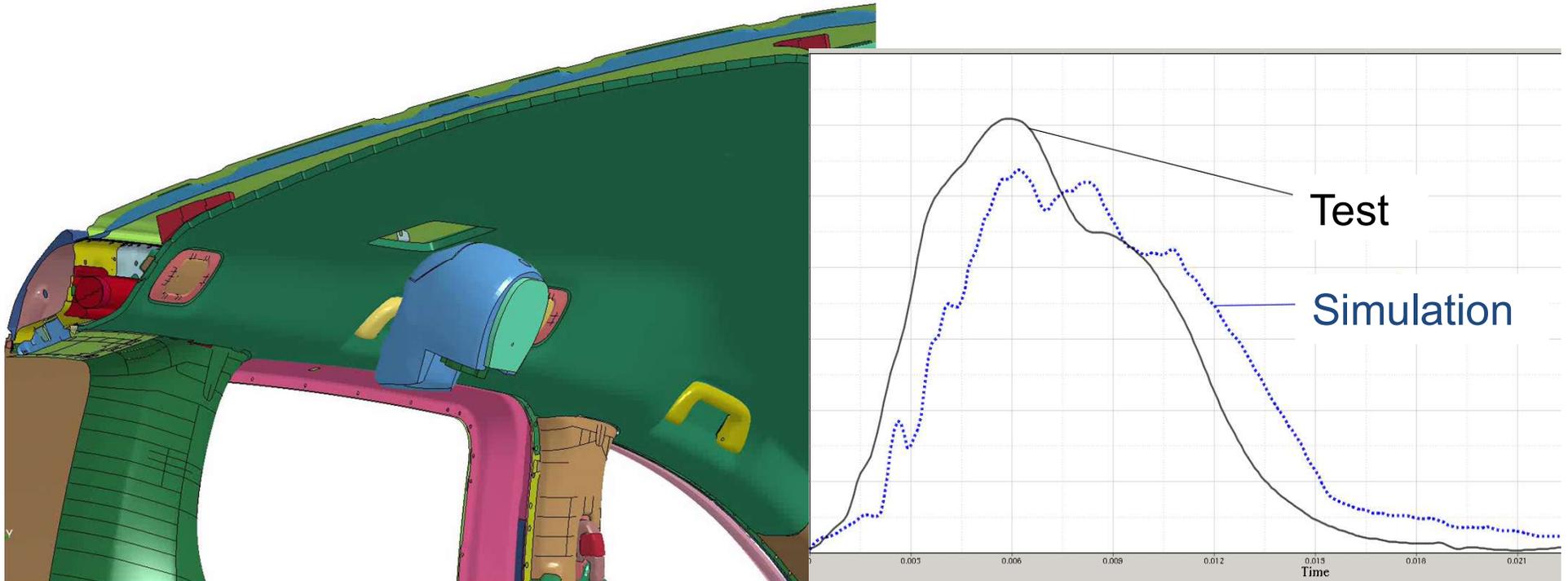
## Windshield glass to airbag



<http://www.latimes.com/>

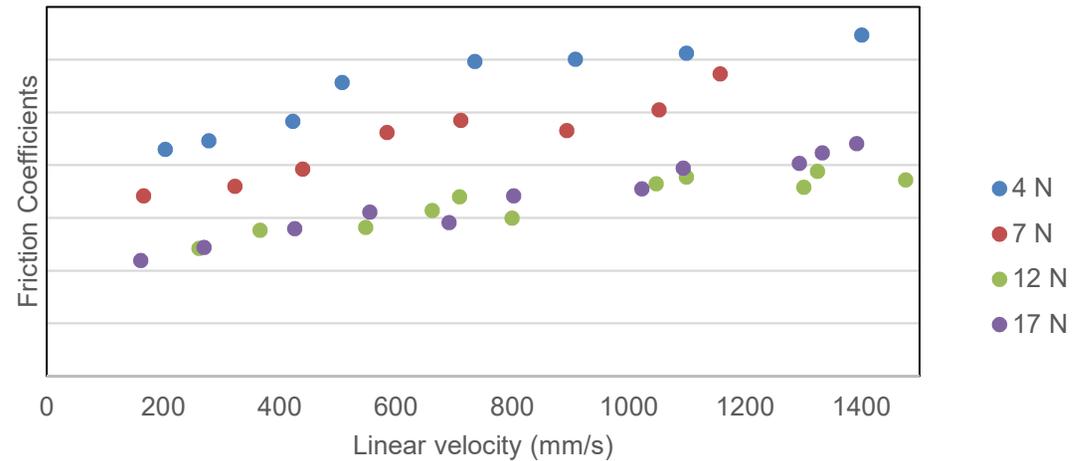


# IMPACT ON ROOF LINER





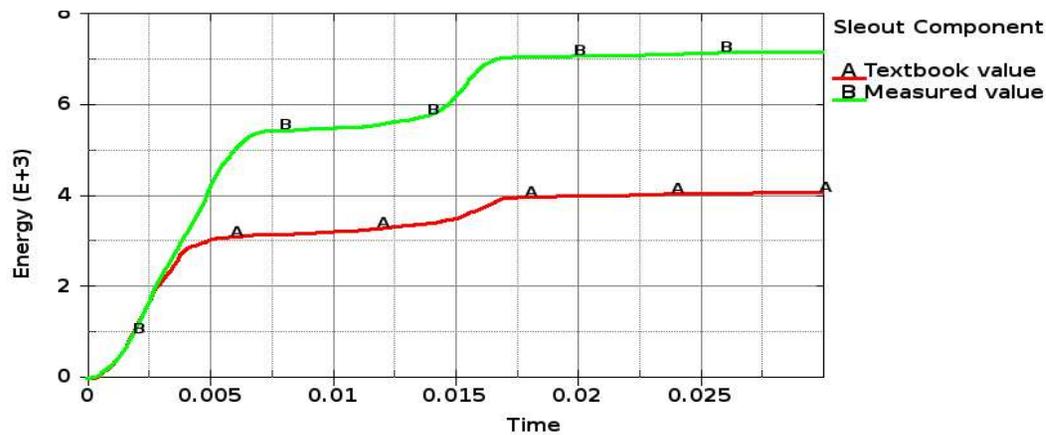
## FRICITION MEASUREMENT



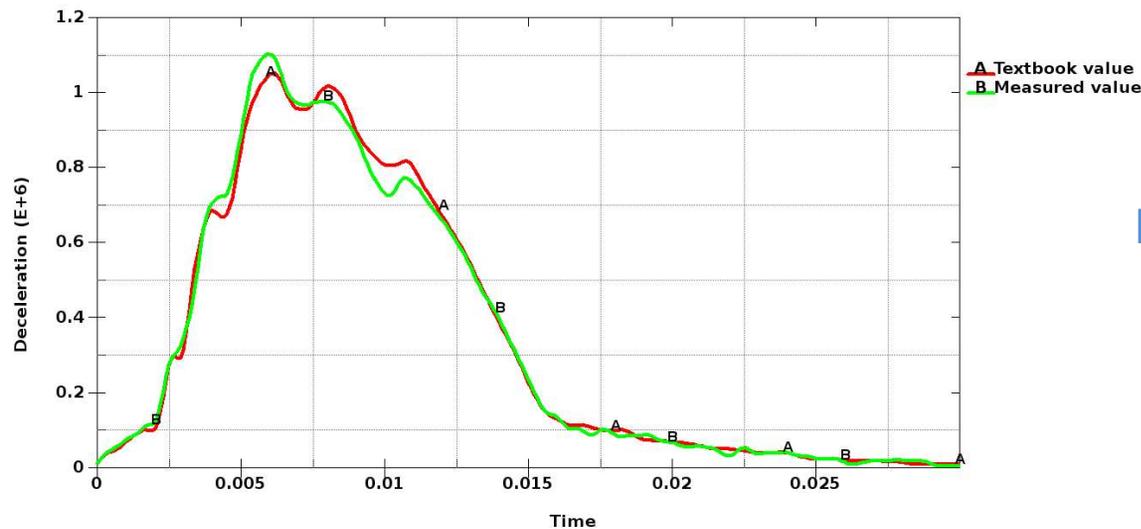
Coefficient from normalized textbook value **0.5** to approximately **1** as measured values



# COMPARISON BETWEEN TEXTBOOK VALUE AND MEASURED VALUE



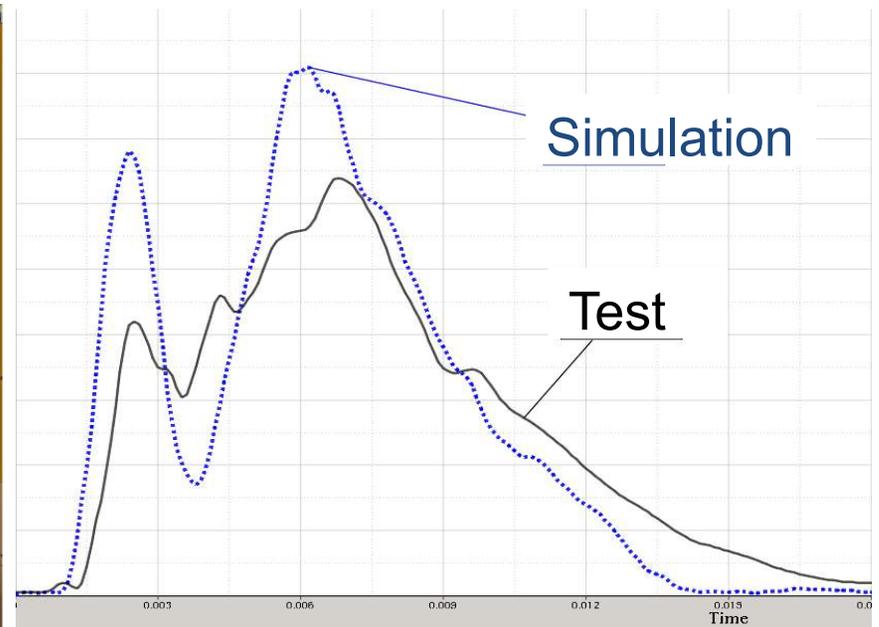
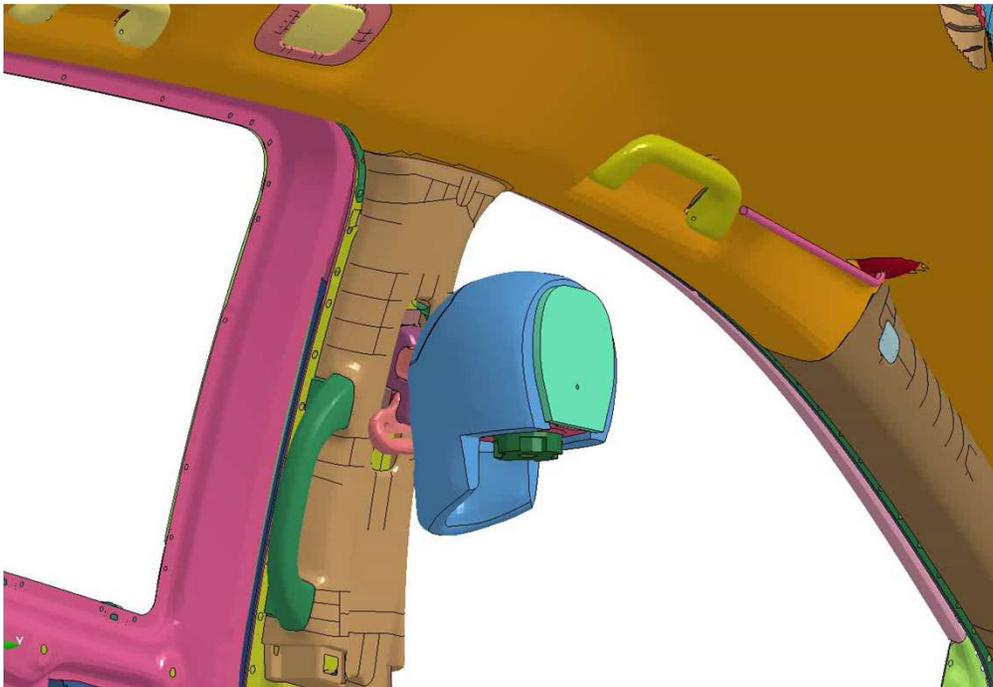
Frictional energy



Deceleration curve

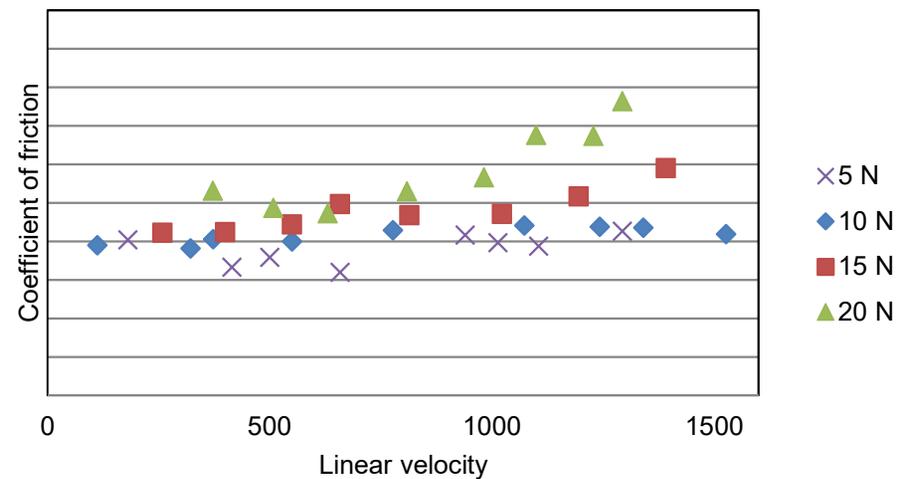
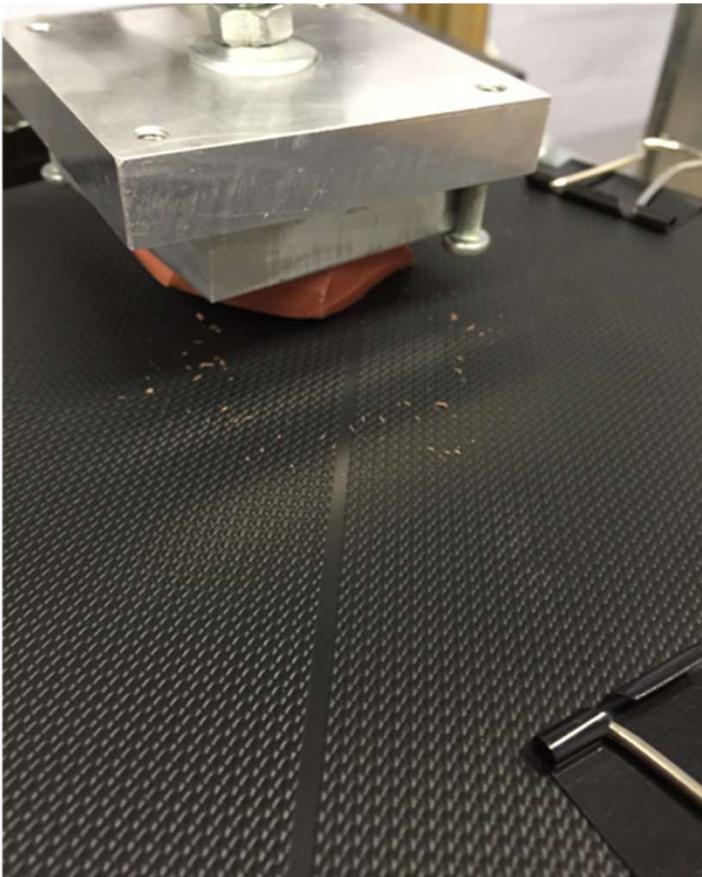


## IMPACT ON B PILLAR





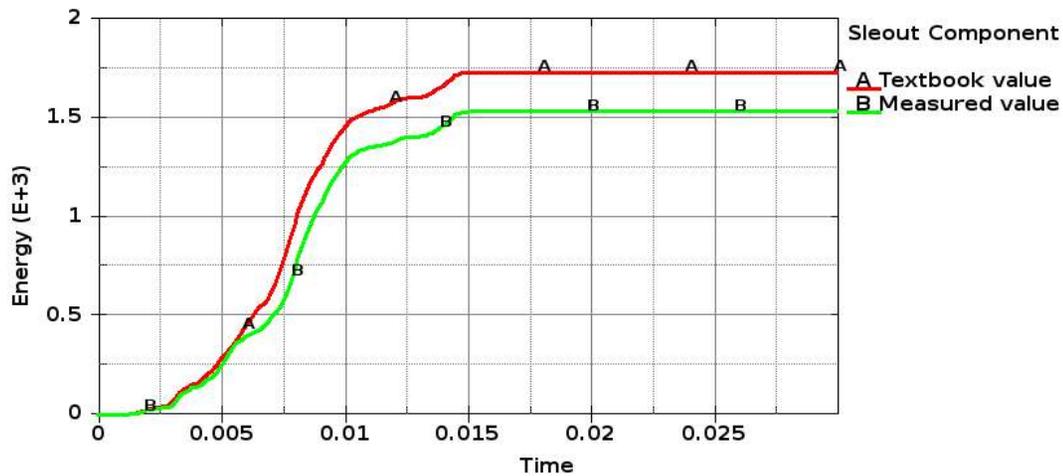
## FRICITION MEASUREMENT



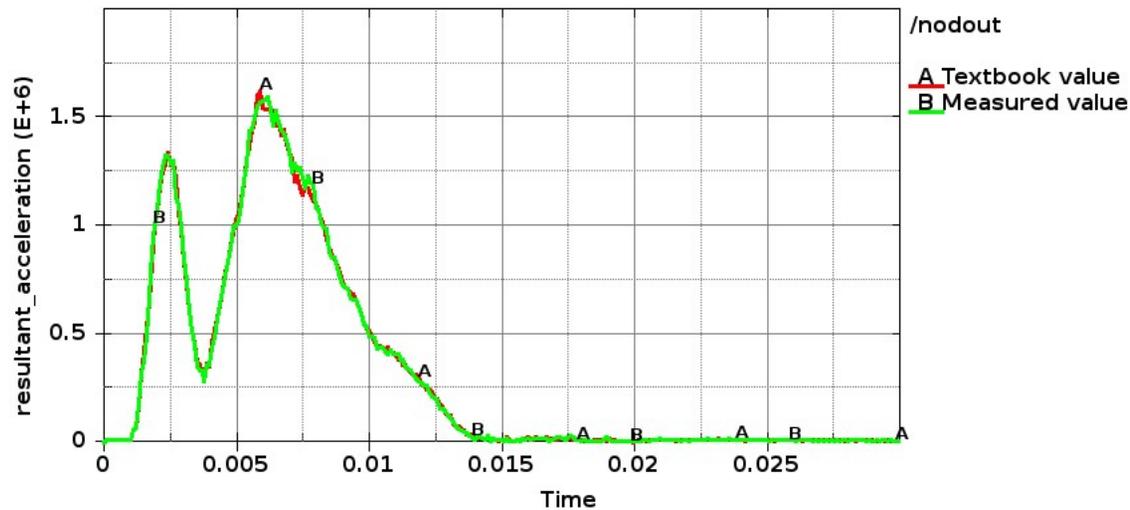
Coefficient from normalized textbook value 1  
To approximately 0.625 as measured values



# COMPARISON BETWEEN TEXTBOOK VALUE AND MEASURED VALUE



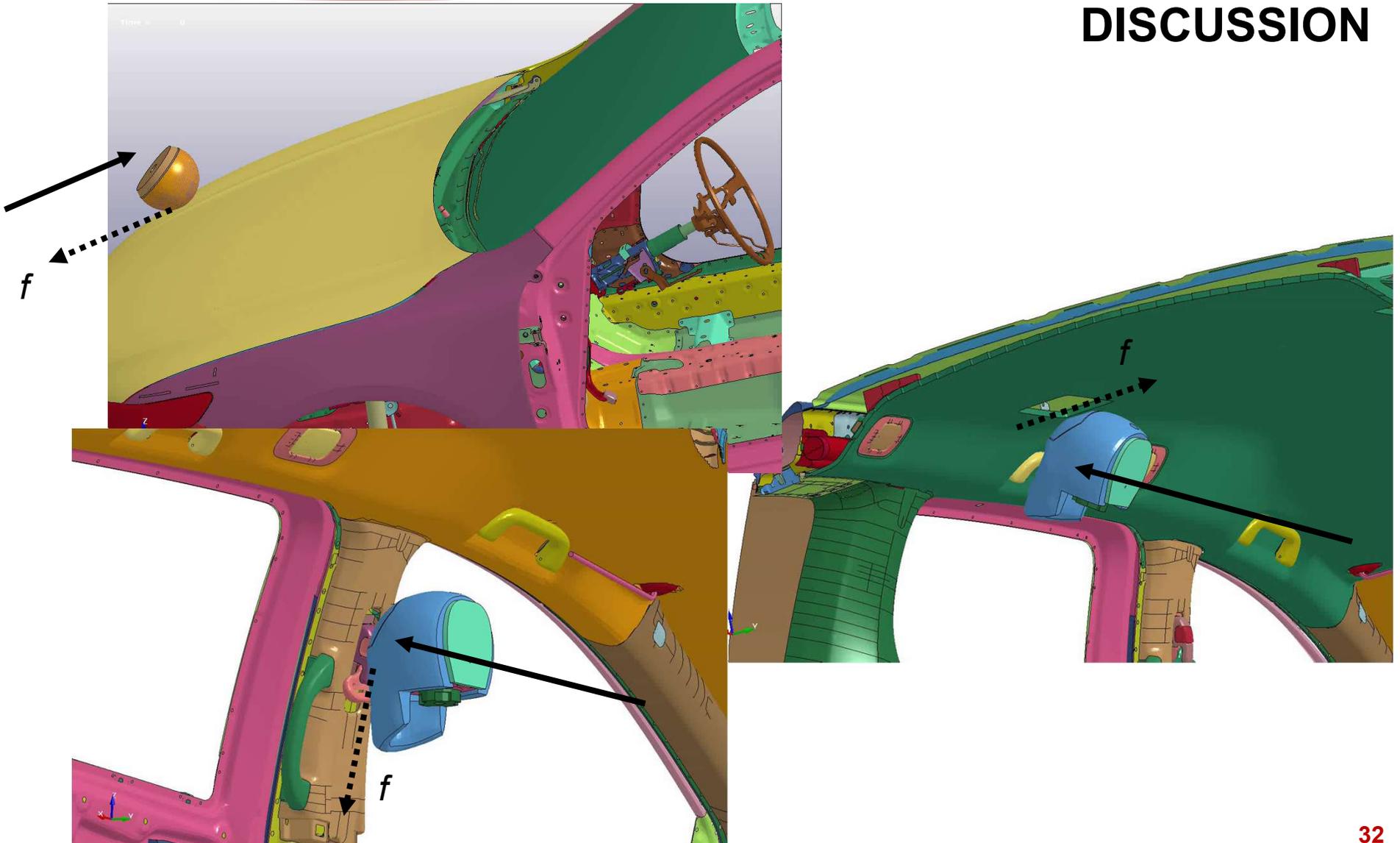
Frictional energy



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!