NHTSA Evaluation of the Flex-GTR Legform on US Vehicles

Brian Suntay & Ann Mallory
Transportation Research Center Inc.

Jason Stammen
NHTSA Vehicle Research and Test Center

Pedestrian Leg Testing

- The Pedestrian Global Technical Regulation (GTR No. 9) includes a projectile leg simulating a moving vehicle hitting a stationary pedestrian at 40 km/h

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Goals of the Testing

- Comparison of vehicle performance with TRL versus Flex-GTR legforms
- Confirm whether the Flex-GTR legform is sensitive enough to distinguish marginally performing vehicles from poor performing vehicles
- Test the Flex-GTR's durability against aggressive locations on US vehicle bumpers

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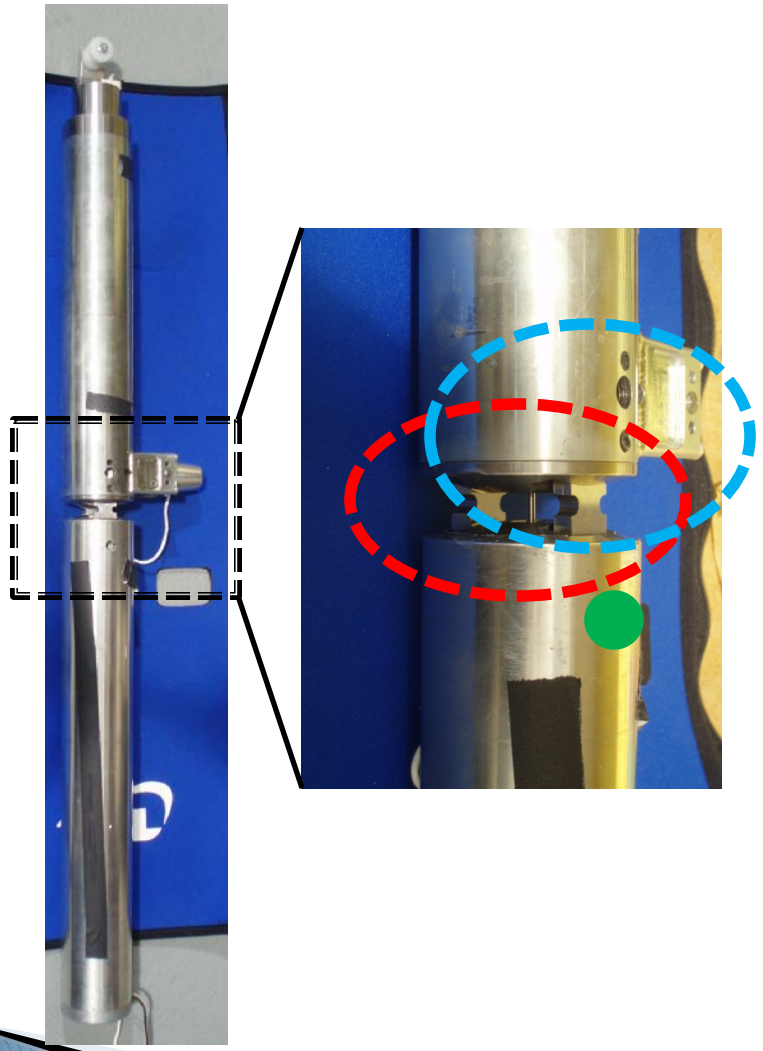
Pedestrian Legforms

TRL

Flex-GTR

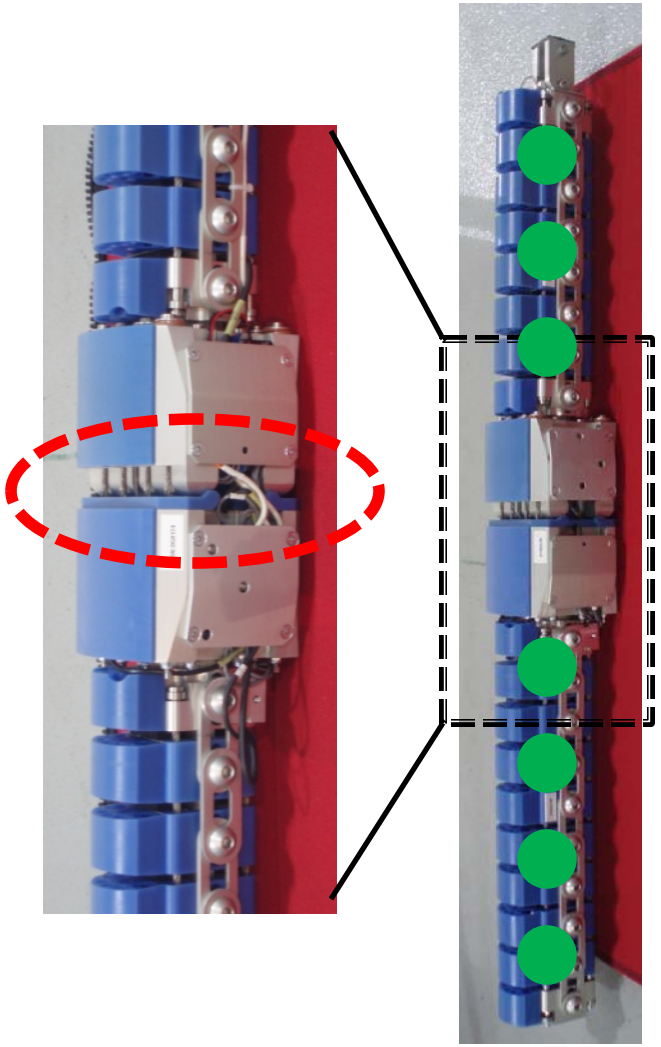
TRL



- Rigid Legform Impactor
- Steel femur and tibia segments
  - Frangible steel ligaments
- Instrumentation:
  - Tibia accelerometer
  - Rotary pot with rigid arm

Flex-GTR

- Flexible Legform Impactor
  - Increased biofidelity
- Flexible bone core, wire ligaments, knee tension cables
- Instrumentation:
  - Tibia and Femur strain gauges
  - Ligament string potentiometers (MCL, ACL, PCL, ACL)



Injury Assessment

Bending Injury Measures

Knee Bending Angle

MCL Elongation

Shear Injury Measures

Knee Shear Displacement

ACL/PCL Elongation

Tibia Fracture Measures

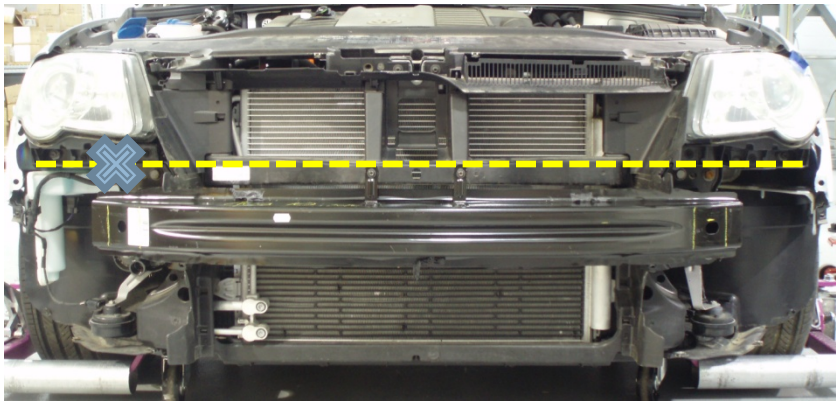
Tibia Acceleration

Tibia Bending Moment

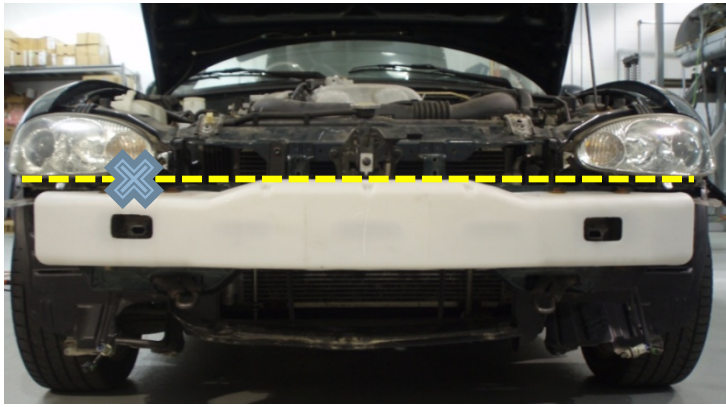
TRL

Flex-GTR

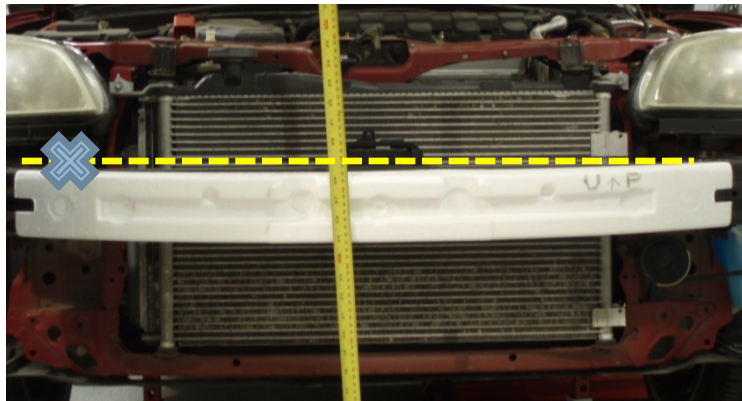
Volkswagen Passat



Mazda Miata



Honda Civic



Honda Pilot

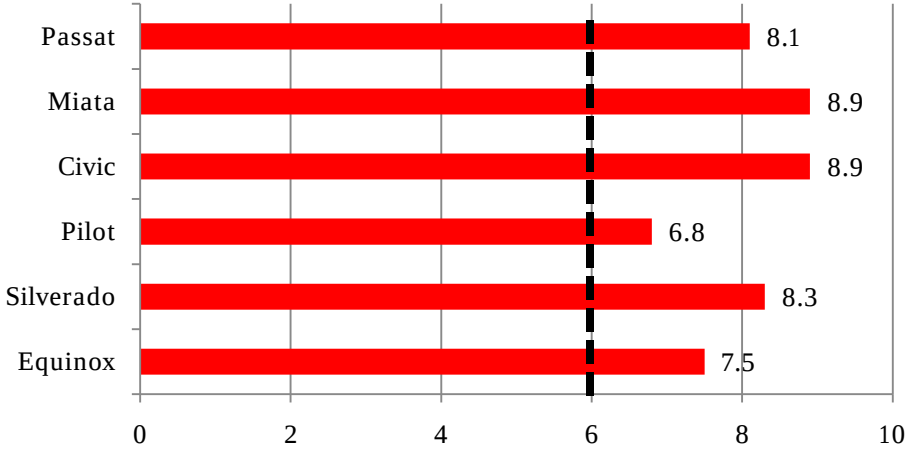
Chevrolet Silverado

Chevrolet Equinox

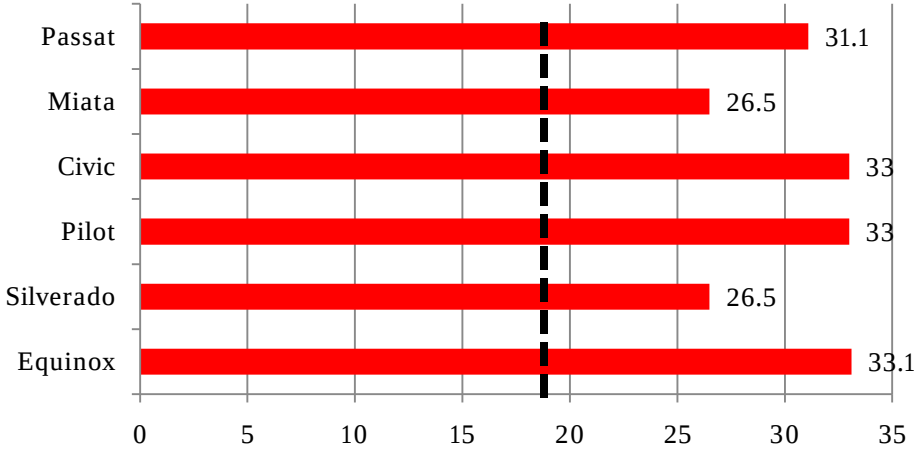
Test Results

TRL Test Results

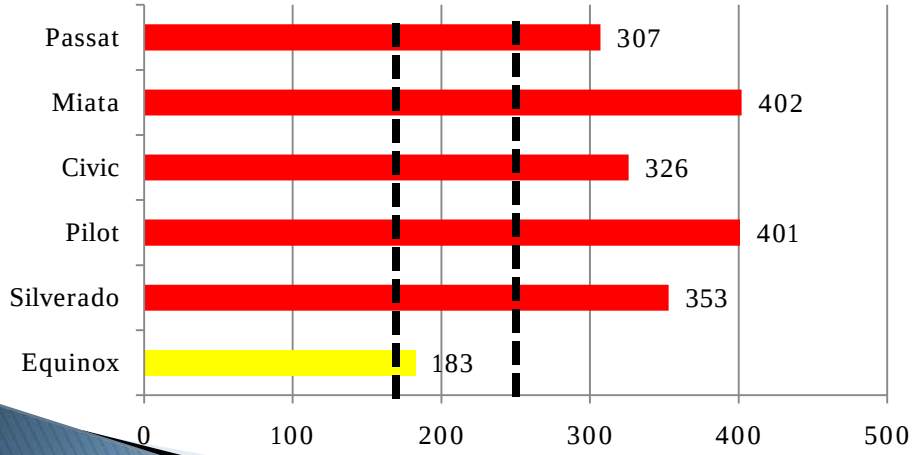
Peak Shear Displacement (mm)

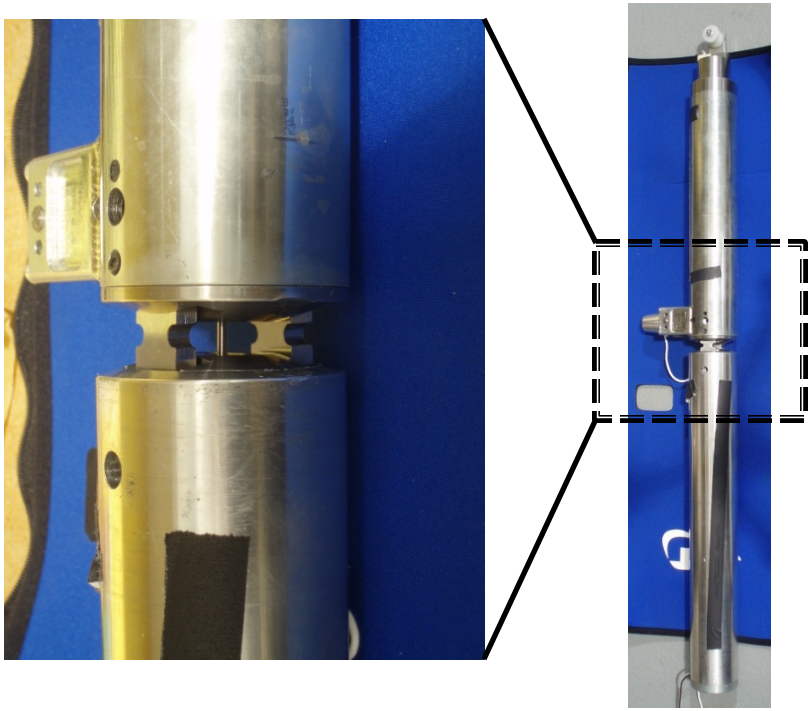


Peak Bending Angle (deg)



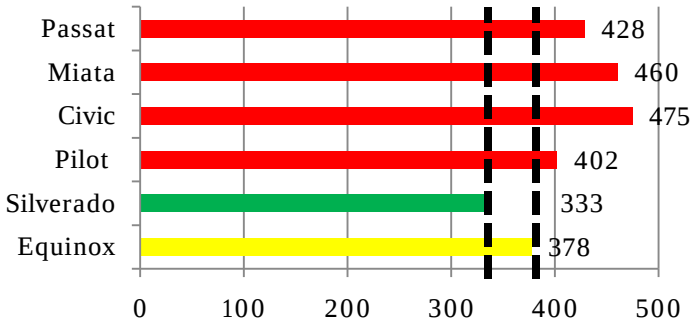
Peak Tibia Acceleration (g)



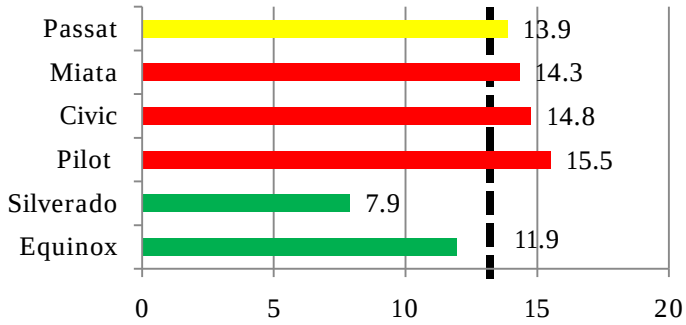


Flex-GTR Test Results

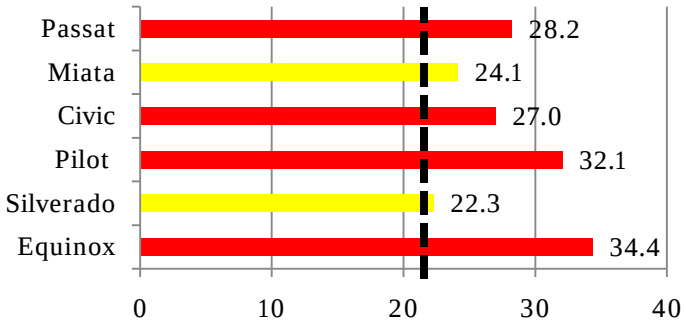
Peak Tibia 1 Moment (Nm)



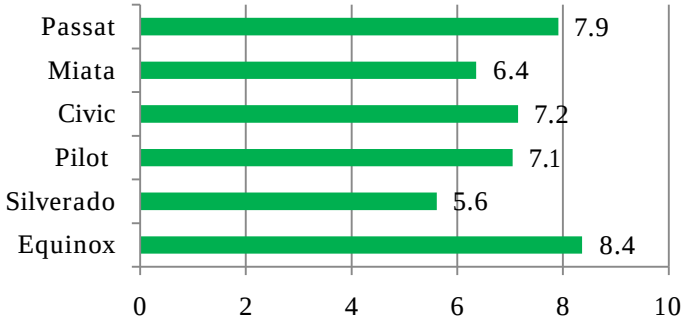
Peak ACL Elongation (mm)

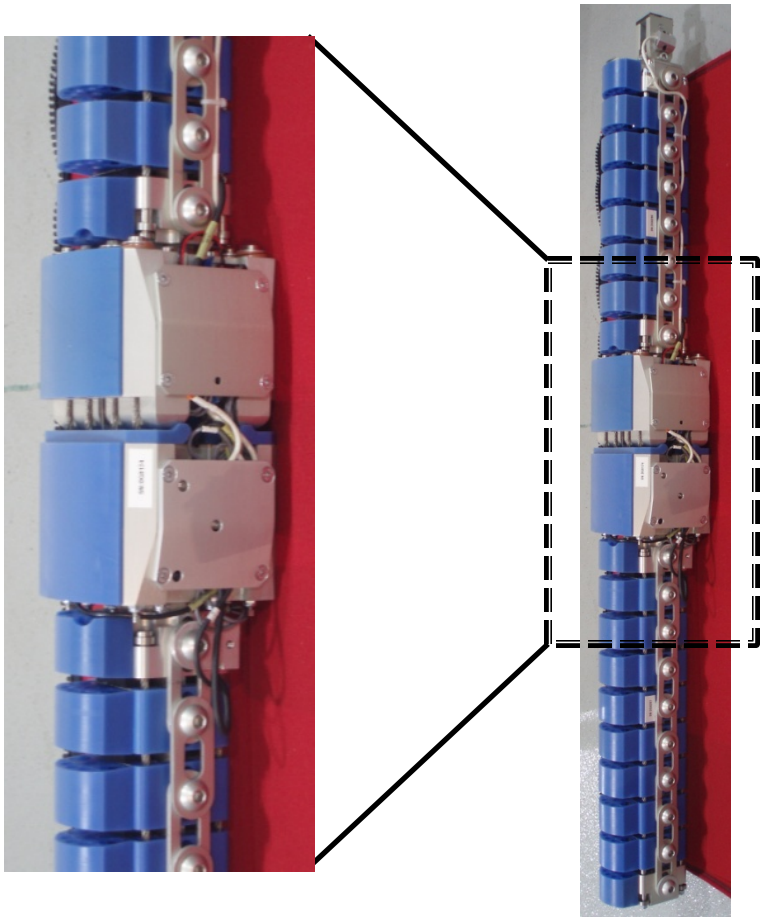


Peak MCL Elongation (mm)



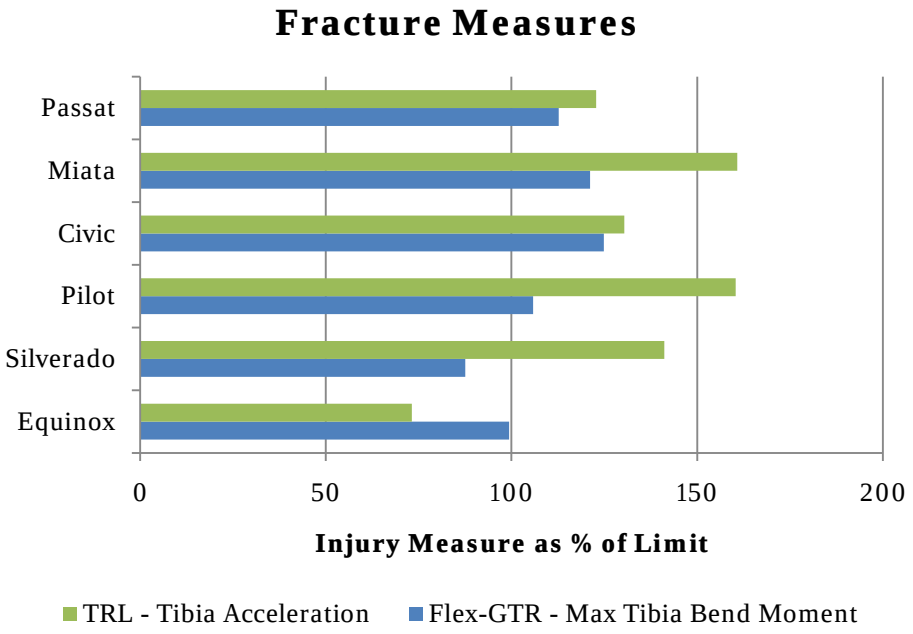
Peak PCL Elongation (mm)

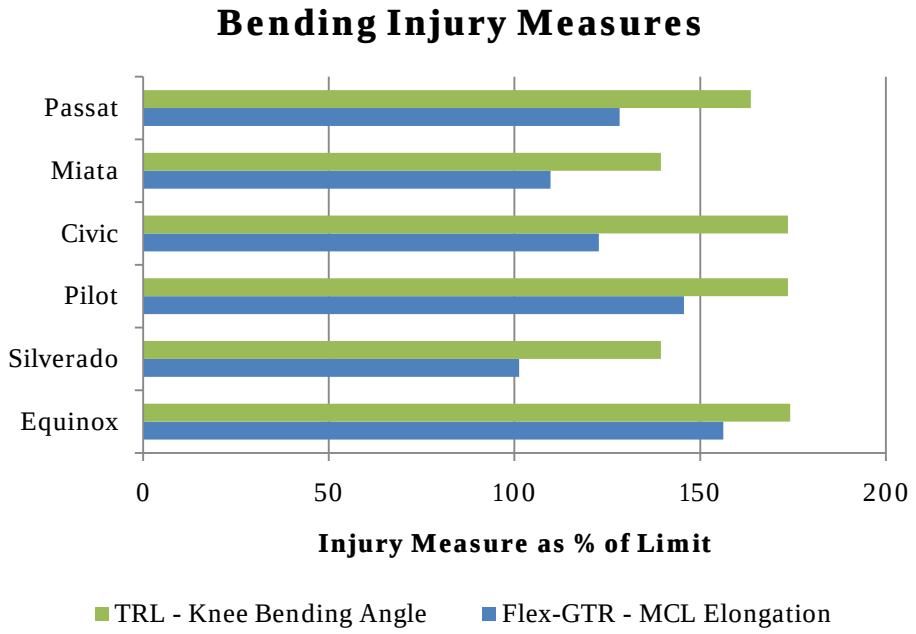


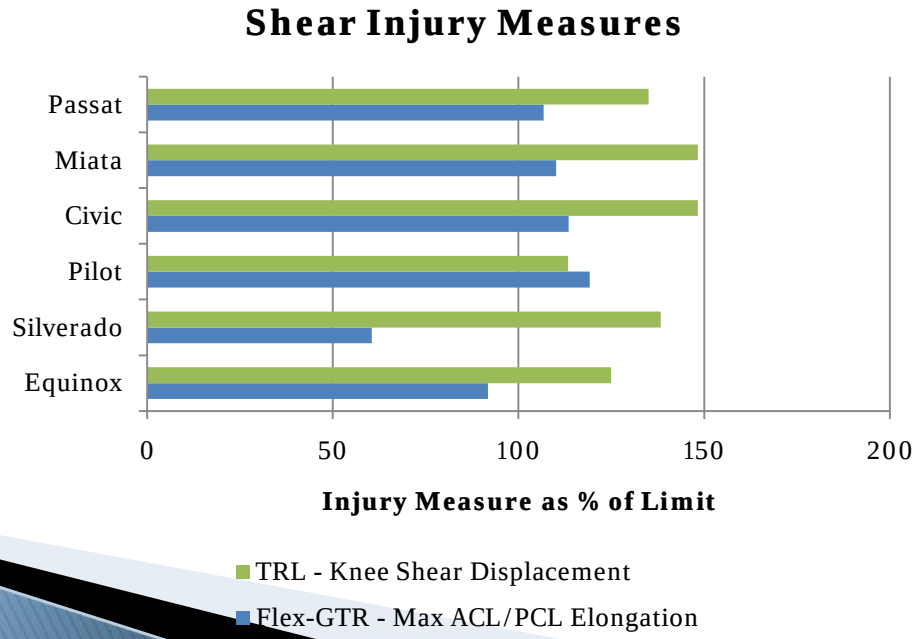


Comparison of Results
TRL vs Flex-GTR

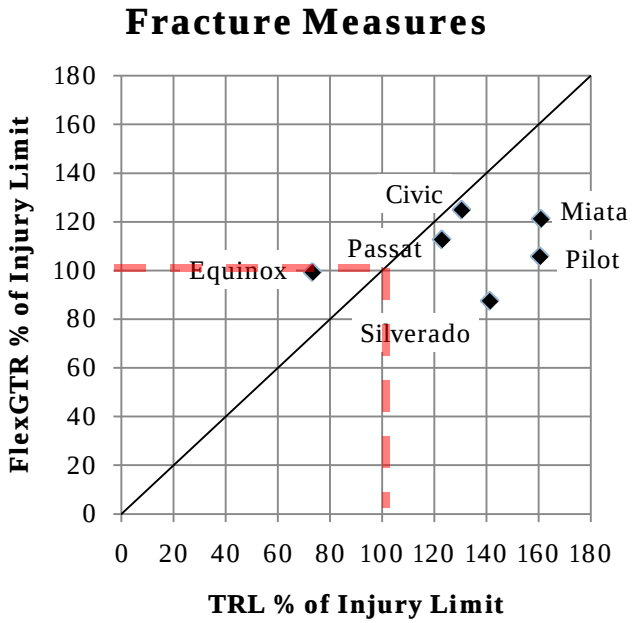
Comparison of Results – TRL vs Flex-GTR

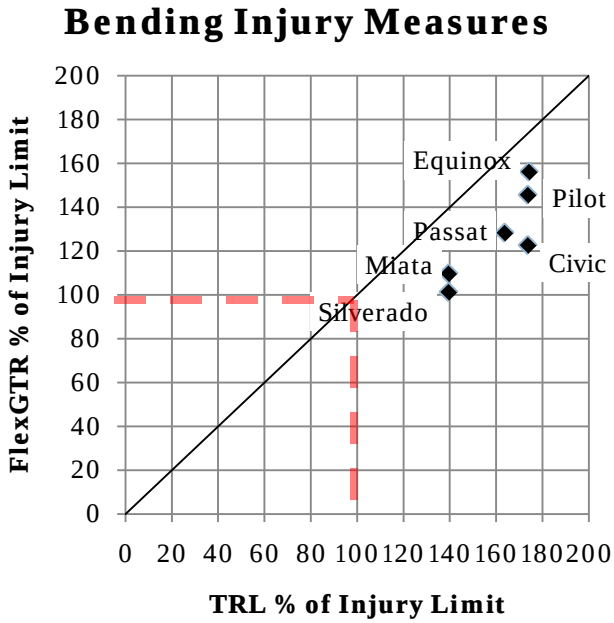


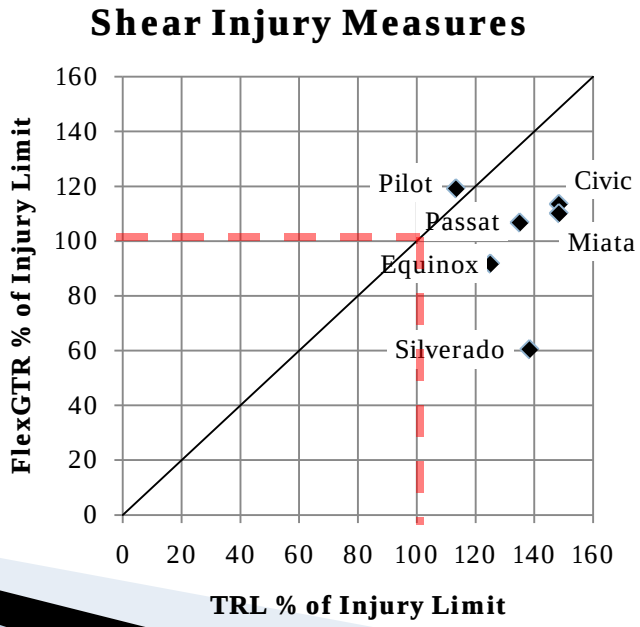




Comparison of Results – TRL vs Flex-GTR







Summary of Findings

- The Flex-GTR measures lower values than the TRL legform with respect to their current injury limits
  - Matsui et al., Characteristics of the TRL Pedestrian Legform and the Flexible Pedestrian Legform Impactors in Car-front Impact Tests, Paper Number 09-0206, 21st International Technical Conference on the Enhanced Safety of Vehicles, 2009.
  - Yoon et al., Evaluation of Usefulness and Repeatability for Pedestrian Protection Flex-PLI, Paper Number 11-0425, 22nd International Technical Conference on the Enhanced Safety of Vehicles, 2011.
- Aggressive vehicle bumper impact locations chosen

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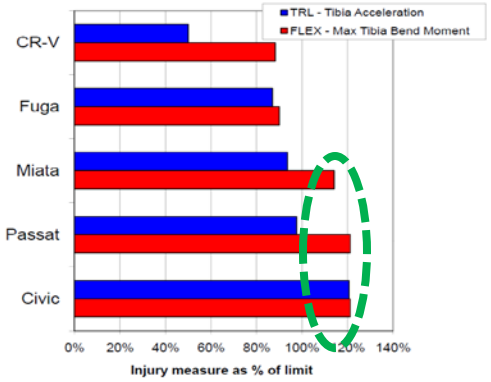
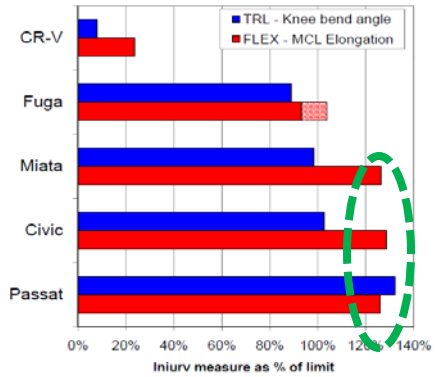
Flex-GTR Vehicle Sensitivity

Sensitivity

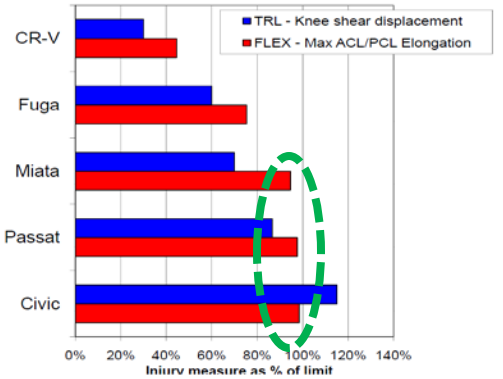
- Testing with a previous version of the Flex-GTR legform suggested an inability of the legform to distinguish among vehicles that performed poorly (Mallory, 2010)



Fracture

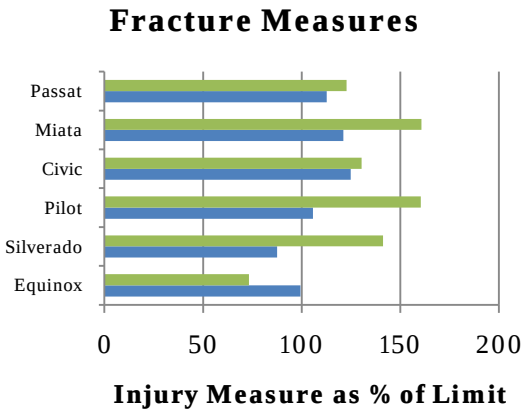


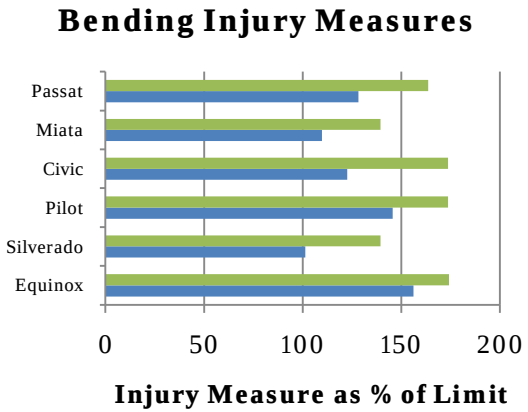
Bend

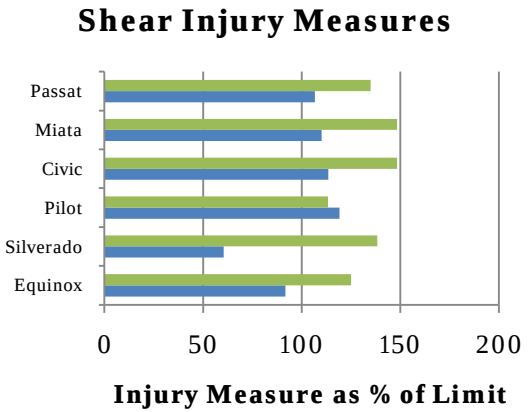


Shear

- Results from current series of tests

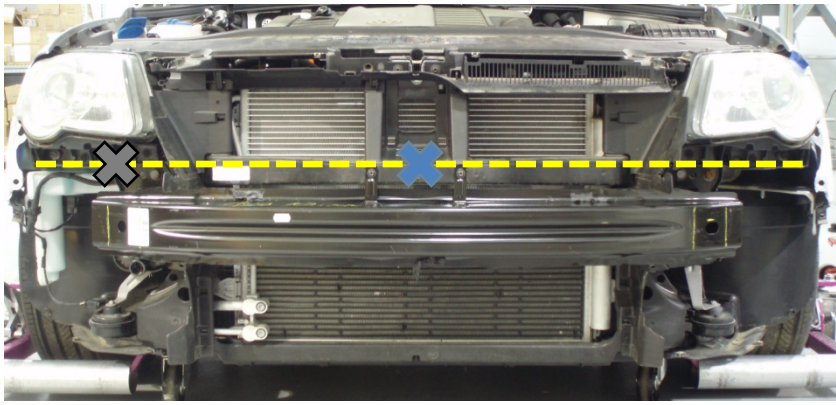






- Three additional tests performed on the center of the three passenger cars

Volkswagen Passat



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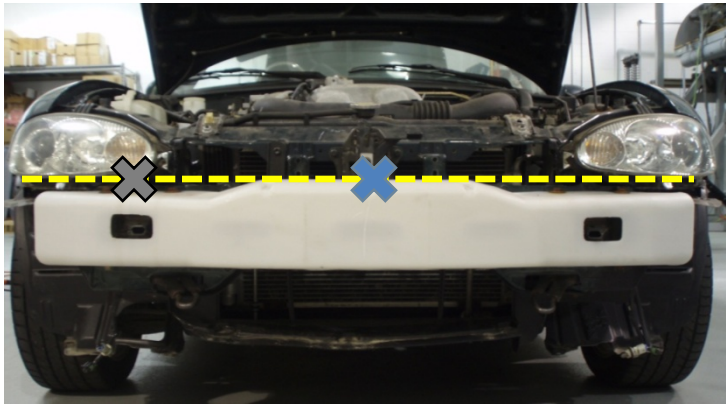

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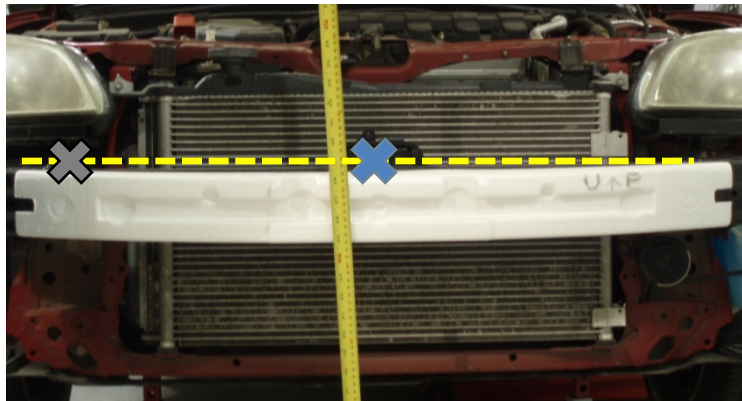
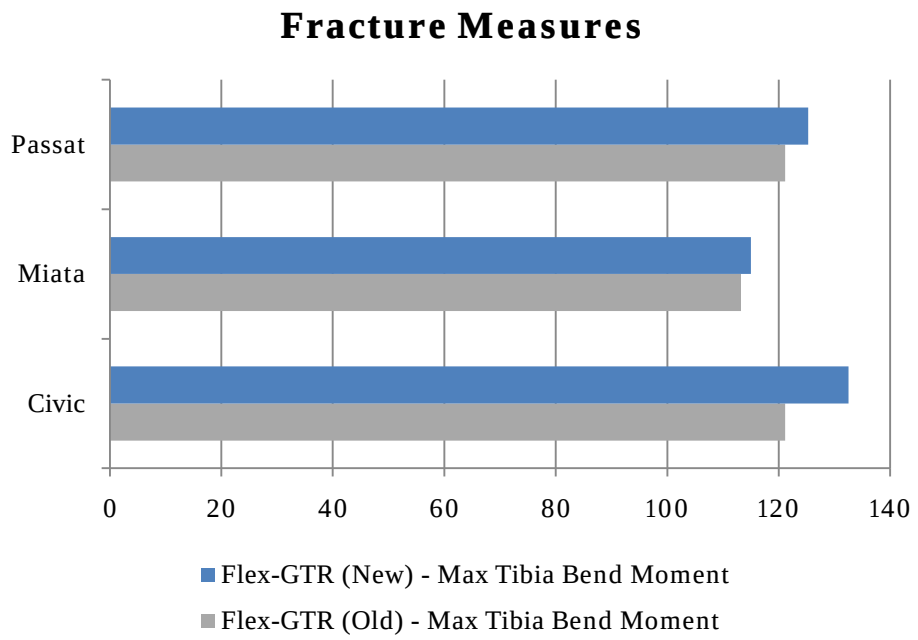
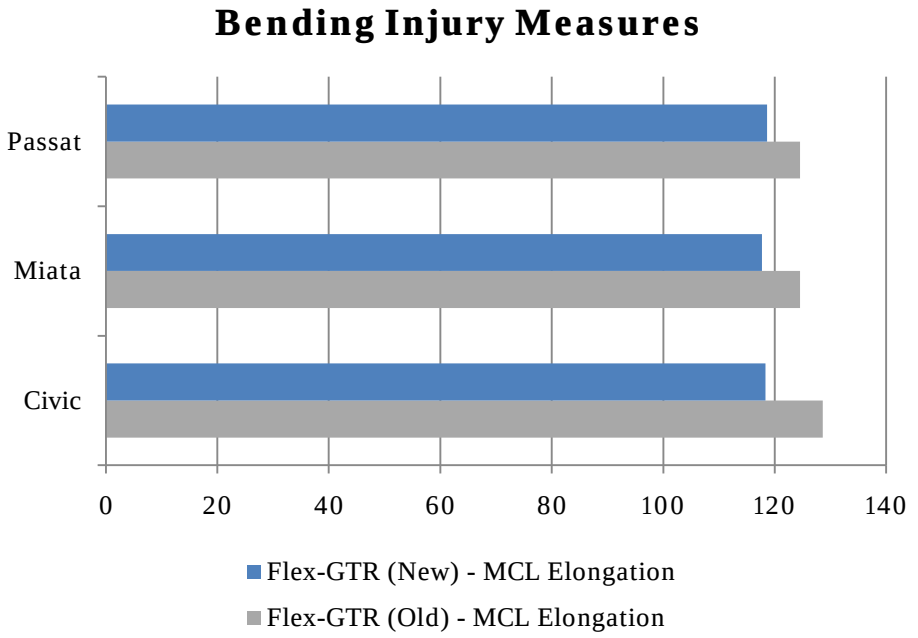
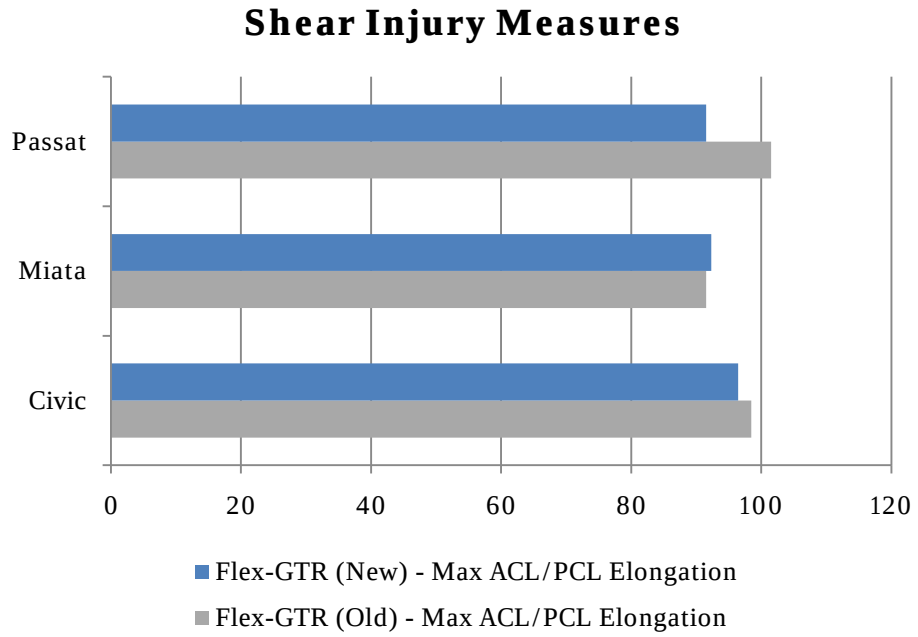


Comparison of Old and New Flex-GTR Data – Center Impacts







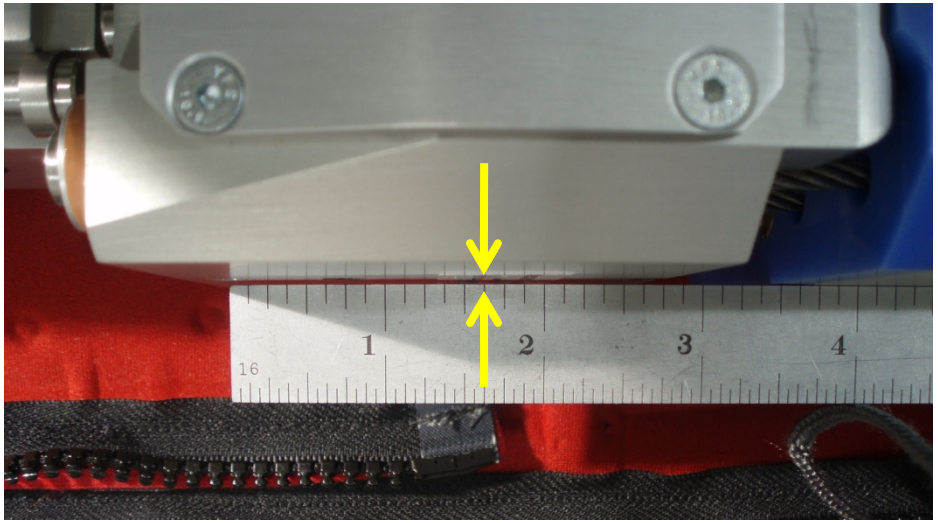
Summary of Findings

- The Flex-GTR measures lower values than the TRL legform with respect to their current injury limits

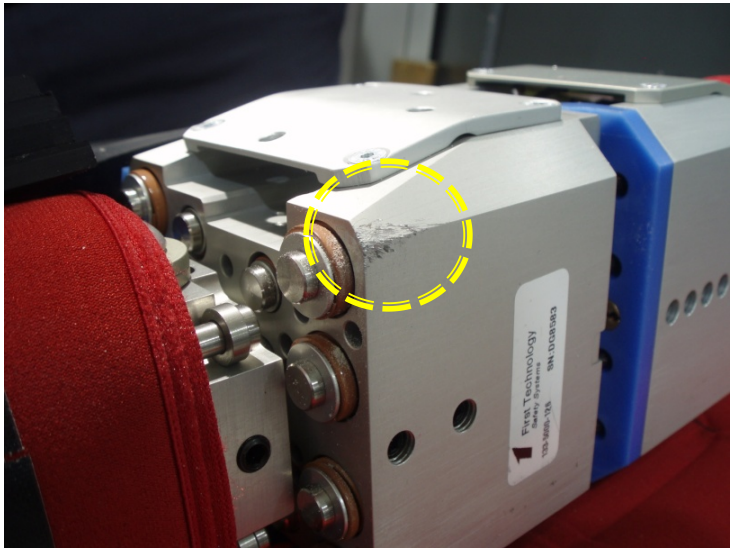
- The Flex-GTR seems to be able to distinguish differences in relatively aggressive vehicle bumper designs

Flex-GTR Durability

Observations and Durability Assessment (Flex-GTR)



Misalignment of the knee after impacts



Tear in the neoprene skin and scratches on the femur knee block

- Femur strain gauge #2 (middle gauge)
  - Broken gauge/wire
  - Still being investigated

Summary of Findings

- The Flex-GTR measures lower values than the TRL legform with respect to their current injury limits
- The Flex-GTR seems to be able to distinguish differences in relatively aggressive vehicle bumper designs
- The Flex-GTR was observed to be durable
  - Survived US vehicle bumper impacts that exceeded injury limits
  - A majority of the issues that were observed were minor and repairable

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Flex-GTR Repeatability
(Additional Observation)

Flex-GTR Repeatability

Injury Measurement		Injury Reference Value (FlexTEG)	Chevrolet Silverado		
Impact Location			Center		
			GTR (1001)	GTR (1002)	%Difference
Femur Moment (Nm)	Femur 3 (Upper)	--*	73.7	77.3	5%
	Femur 2 (Middle)		139.5	138.5	1%
	Femur 1 (Lower)		252.1	245.6	3%
Tibia Moment (Nm)	Tibia 1 (Upper)	340 Nm (380 Nm)	**332.7**	**332.6**	**0%**
	Tibia 2 (Mid Upper)		311.1	319.5	3%
	Tibia 3 (Mid Lower)		233.5	237.4	2%
	Tibia 4 (Lower)		110.5	107.9	2%
MCL Elongation (mm)		22 mm	**--**	**22.3**	**NA**
ACL Elongation (mm)		13 mm	**8**	**7.9**	**1%**
PCL Elongation (mm)		13 mm	**5.4**	**5.6**	**4%**
LCL Elongation (mm)		--*	-4.2	-3.8	10%
Tibia Acceleration (g)		--*	-59.2	-59.5	1%
Velocity (m/s)		--*	11.1	11.1	0%
				Average:	3%

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Summary of Findings

- The Flex-GTR measures lower values than the TRL legform with respect to their current injury limits
- The Flex-GTR seems to be able to distinguish differences in relatively aggressive vehicle bumper designs
- The Flex-GTR was observed to be durable
  - Survived US vehicle bumper impacts that exceeded injury limits
  - A majority of the issues that were observed were minor and repairable
- Flex-GTR repeatability was not directly evaluated, but
  - Silverado Flex-GTR tests 1001 and 1002 showed similar values at the same impact location, which is promising

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