

Informal document GRSP-49-23
(49th GRSP, 16-20 May 2011,
agenda items 4(a))

Update on Pedestrian Leg Testing

**National Highway Traffic Safety
Administration**

49th GRSP Session

May 2011

Nha Nguyen



Pedestrian Leg Testing

- Projectile leg simulates a moving vehicle hitting a stationary pedestrian



Pedestrian Legforms



TRL



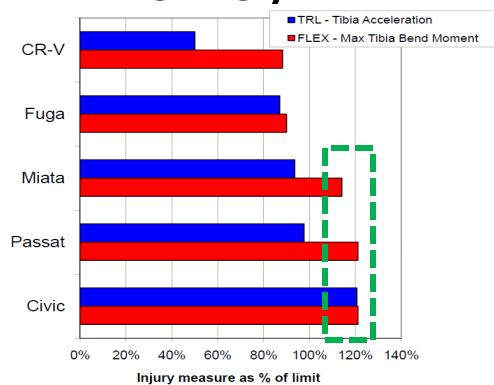
Flex-GT



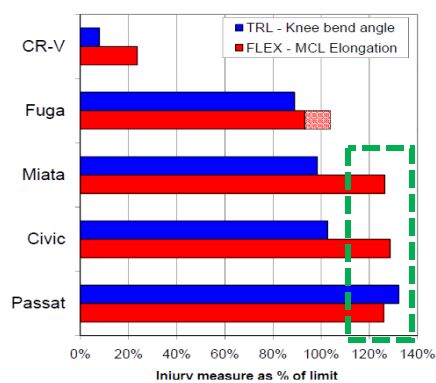
Flex-GTR

Background

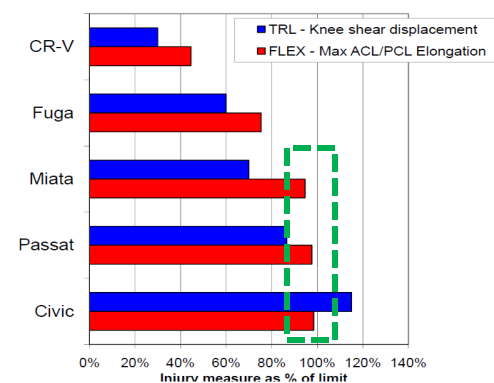
- The Flex-GTR had not been tested against aggressive vehicles in the US fleet and there was concern about its durability
- There was also concern about topping out the Flex-GTR's measurement limits (Mallory, 2010)



Fracture



Bend



Shear

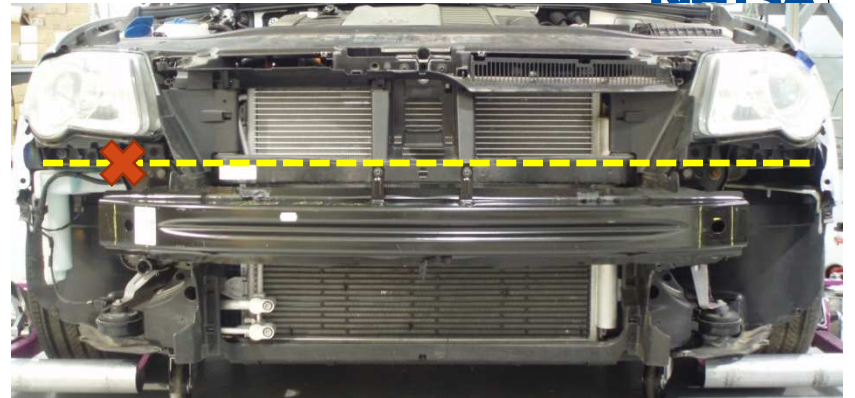
Goals of the Testing

- This series of impacts was done to test the Flex-GTR against aggressive US vehicles to see if it would survive
- Confirm whether the Flex-GTR legform can distinguish marginally performing vehicles from poor performing vehicles

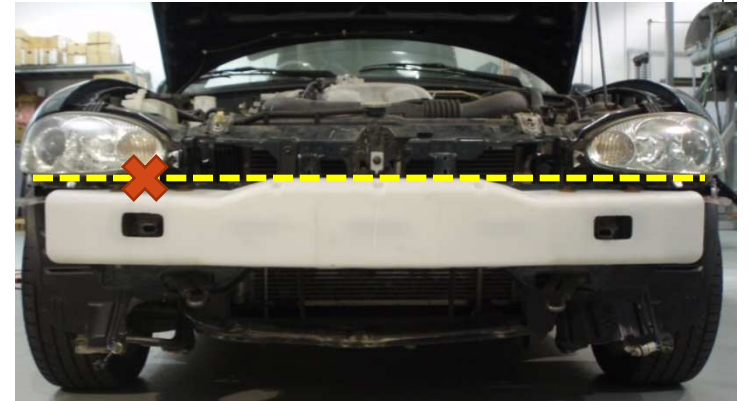
Test Sequence

- Due to durability concerns, the TRL legform was tested on each vehicle first to rank the vehicles in order of increasing aggressiveness
- The Flex-GT was then tested on each vehicle to rank them for the Flex-GTR tests
- This allows us to get in as many tests as possible before possibly damaging the legform

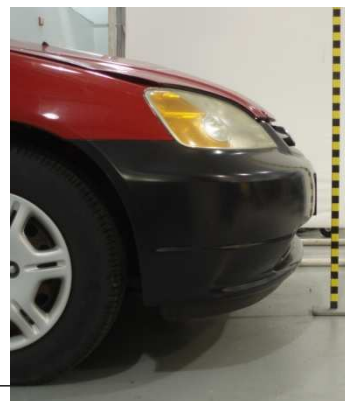
Volkswagen Passat



Mazda Miata



Honda Civic



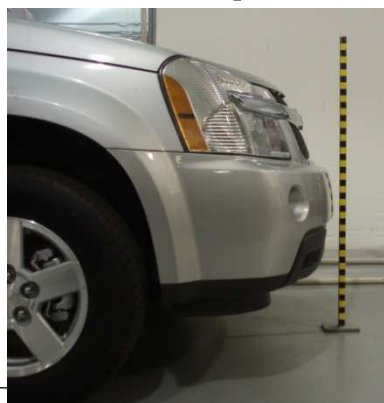
Honda Pilot



Chevrolet Silverado



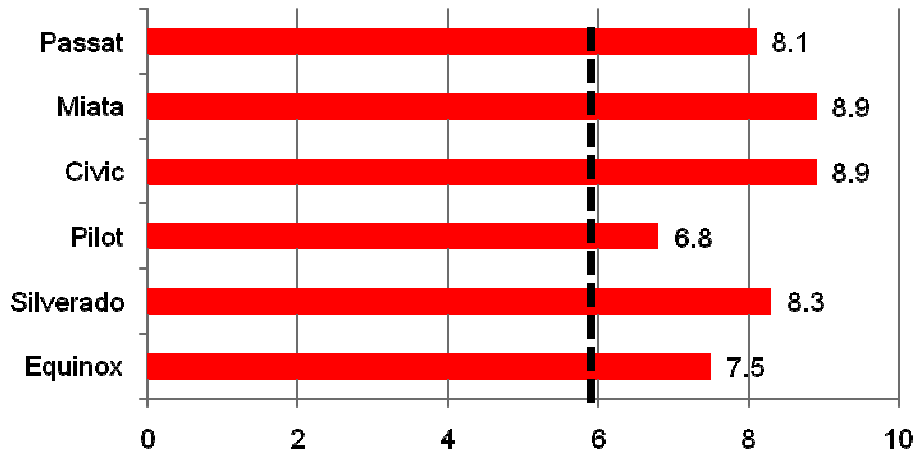
Chevrolet Equinox



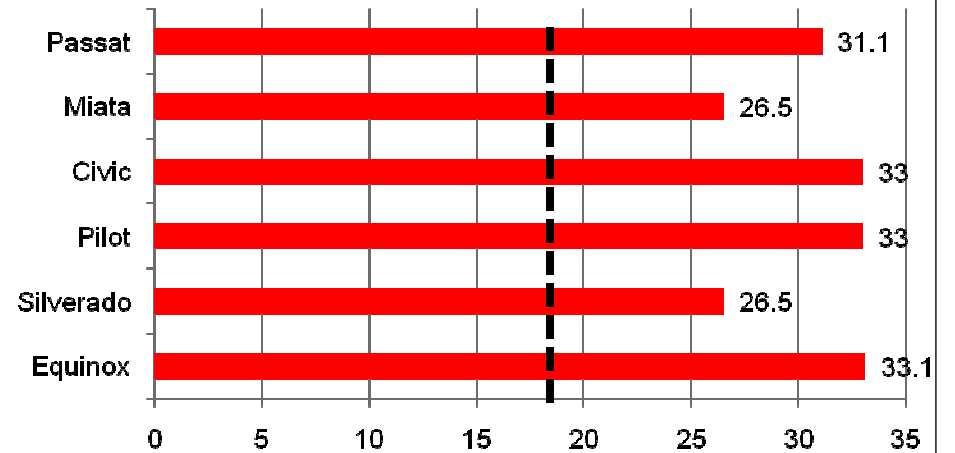
Test Results

TRL Test Results

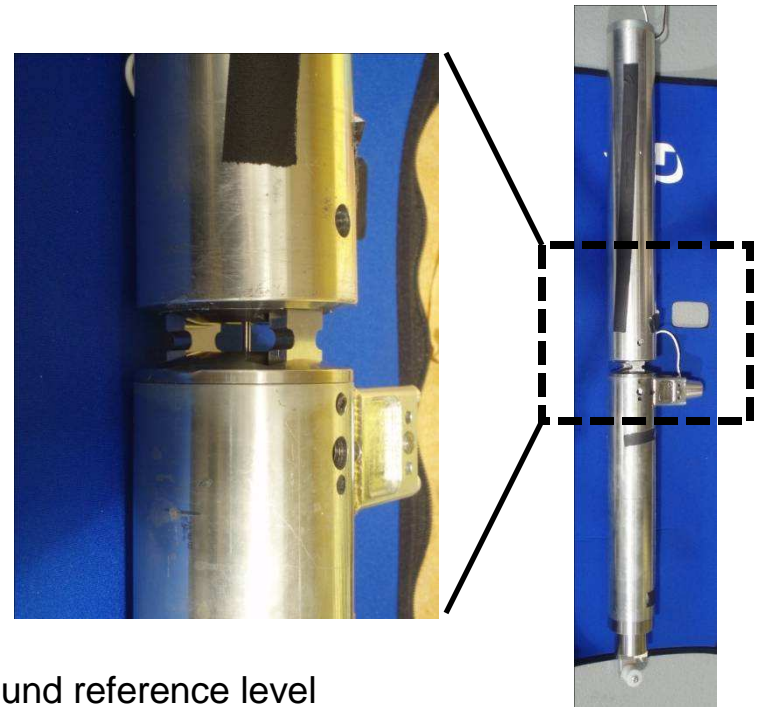
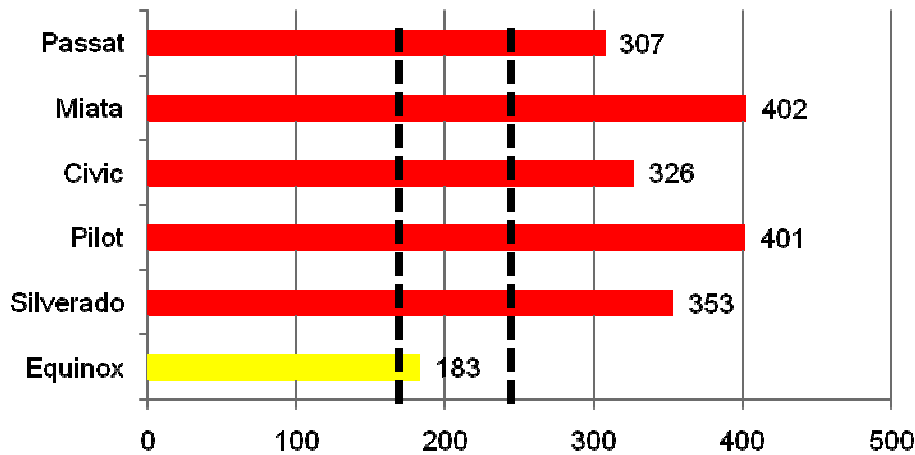
Peak Shear Displacement (mm)



Peak Bending Angle (deg)

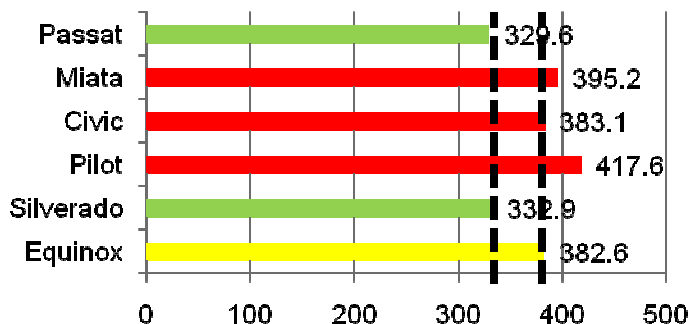


Peak Tibia Acceleration (g)

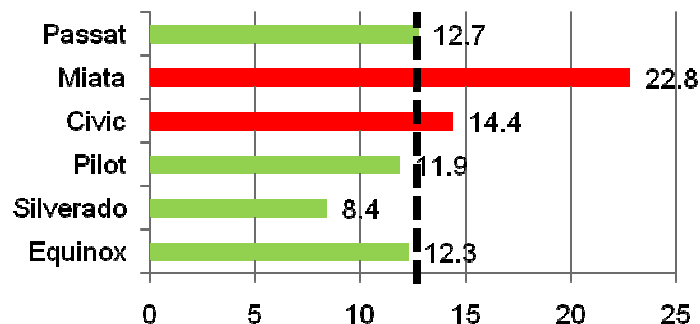


Flex-GT Test Results

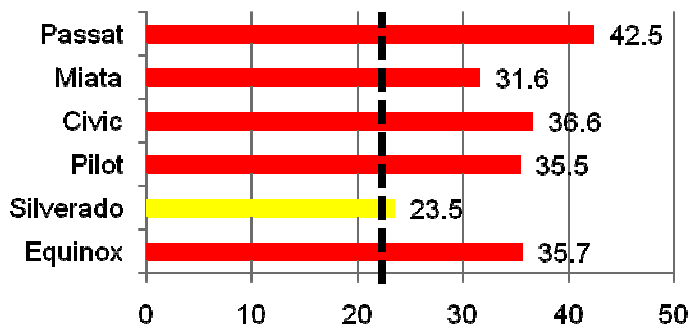
Peak Tibia 1 Moment (Nm)



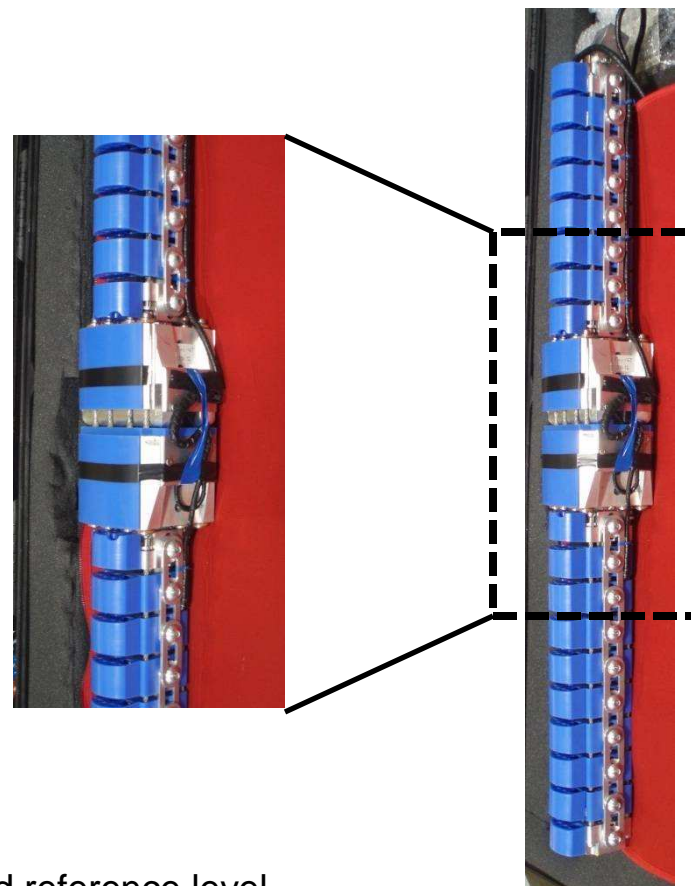
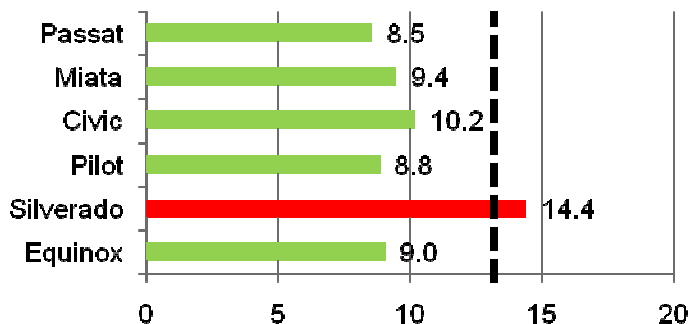
Peak ACL Elongation (mm)



Peak MCL Elongation (mm)



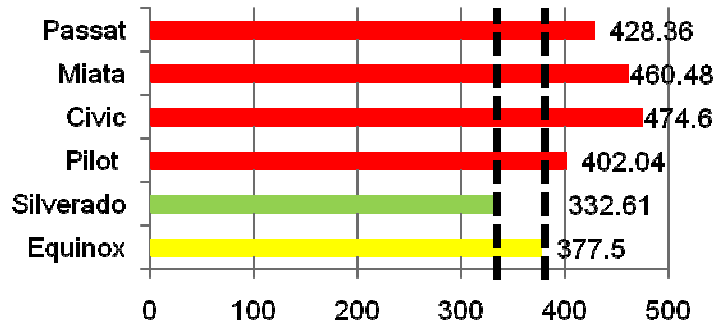
Peak PCL Elongation (mm)



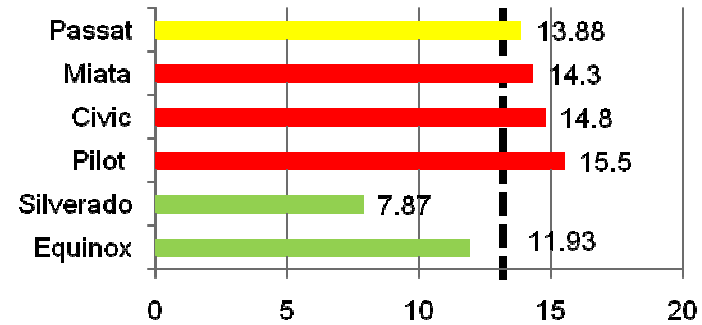
*Performed under GTR conditions with legform 25 mm above ground reference level

Flex-GTR Test Results

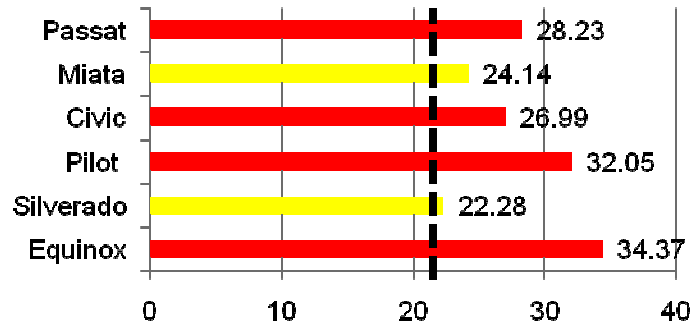
Peak Tibia 1 Moment (Nm)



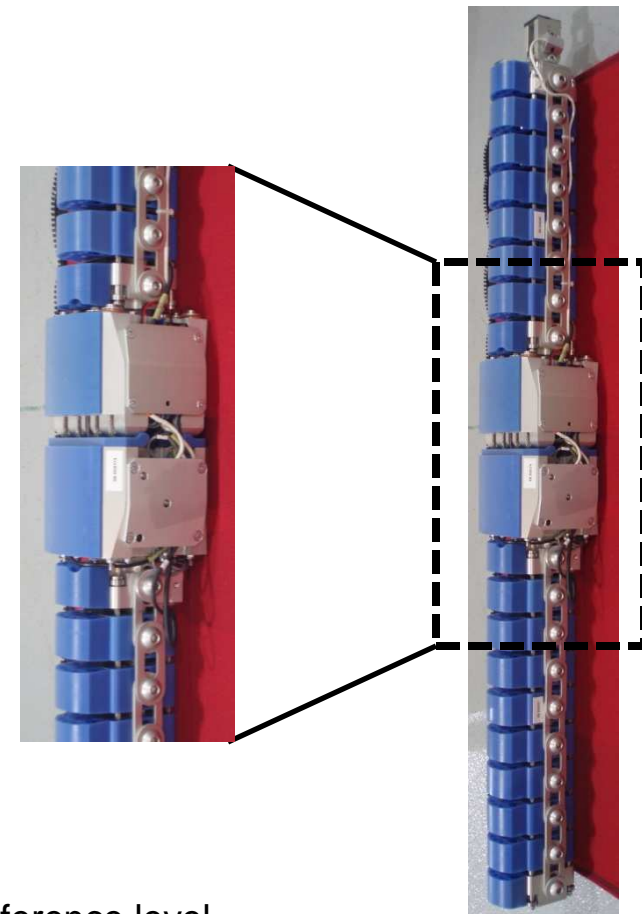
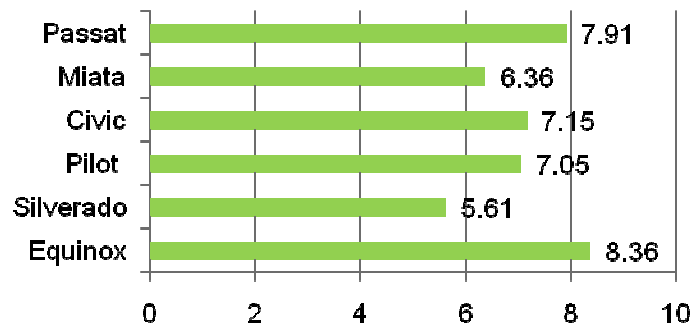
Peak ACL Elongation (mm)



Peak MCL Elongation (mm)



Peak PCL Elongation (mm)

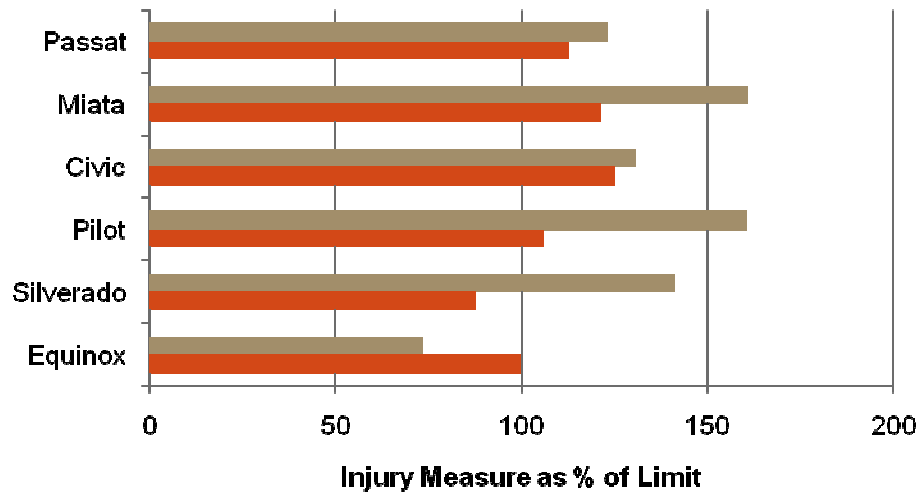


*Performed under GTR conditions with legform 75 mm above ground reference level

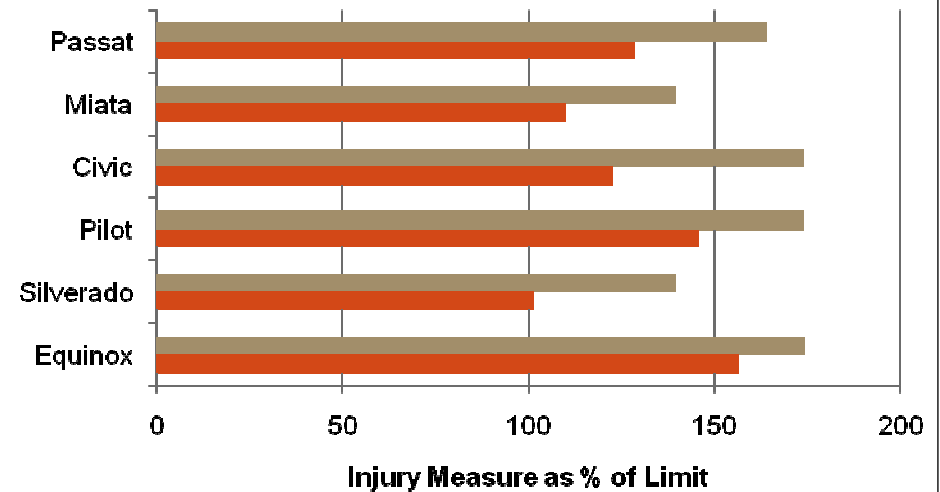
Comparison of Results TRL vs GTR

Comparison of Results – TRL vs Flex-GTR

Fracture Measures



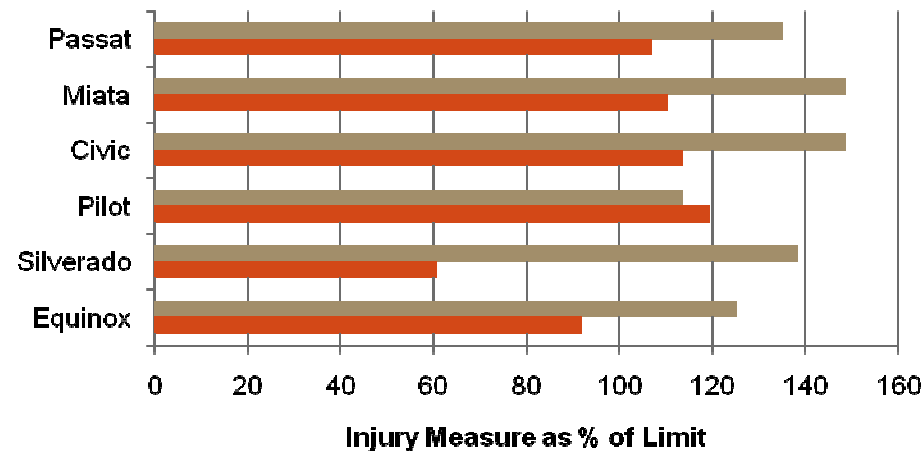
Bending Injury Measures



■ TRL - Tibia Acceleration ■ Flex-GTR - Max Tibia Bend Moment

■ TRL - Knee Bending Angle ■ Flex-GTR - MCL Elongation

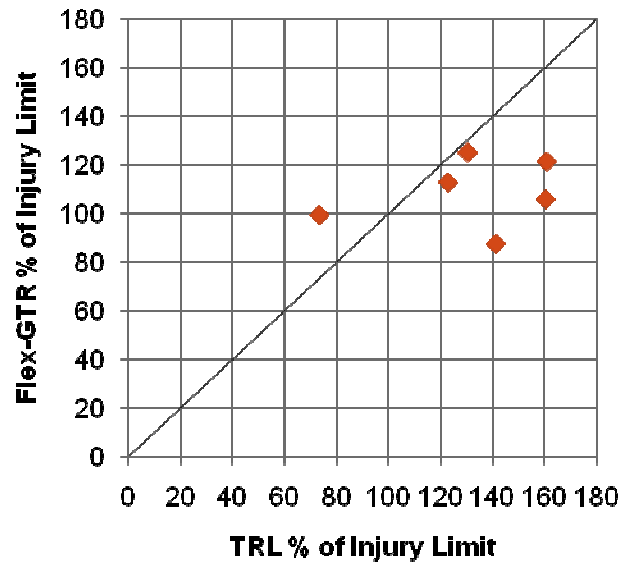
Shear Injury Measures



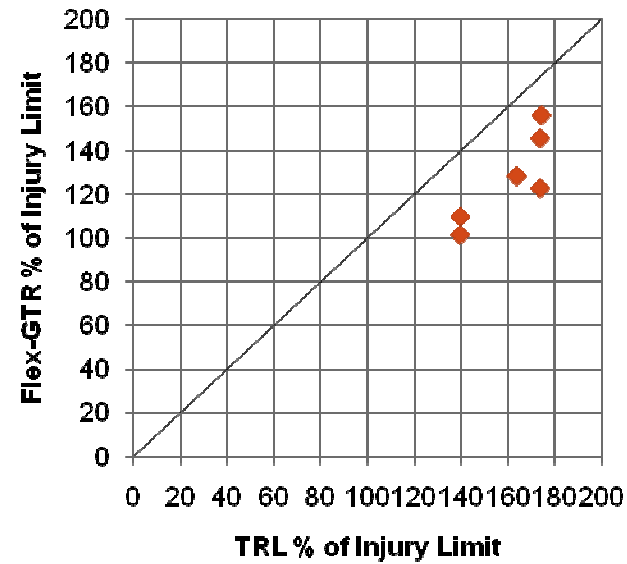
■ TRL - Knee Shear Displacement
 ■ Flex-GTR - Max ACL/PCL Elongation

Comparison of Results – TRL vs Flex-GTR

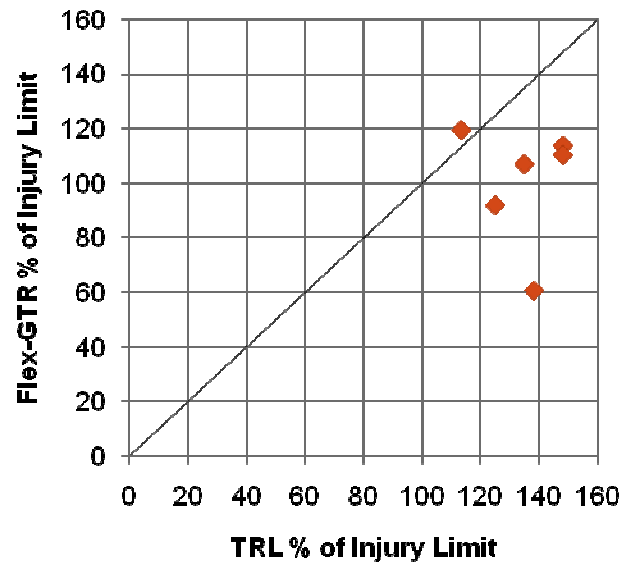
Fracture Measures



Bending Injury Measures



Shear Injury Measures

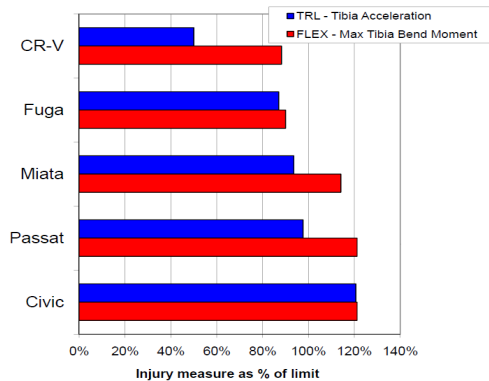


Summary of Findings

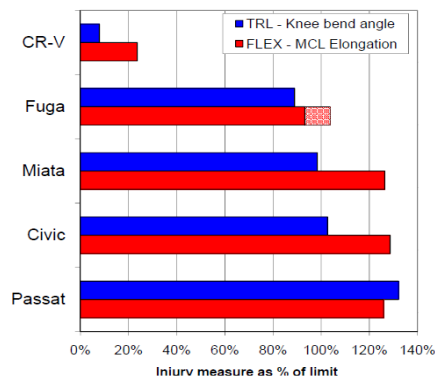
- The Flex-GTR measures lower values than the TRL legform
- The current Flex-GTR seems to be able to distinguish differences in relatively aggressive vehicle bumper designs better than the previous version

Sensitivity

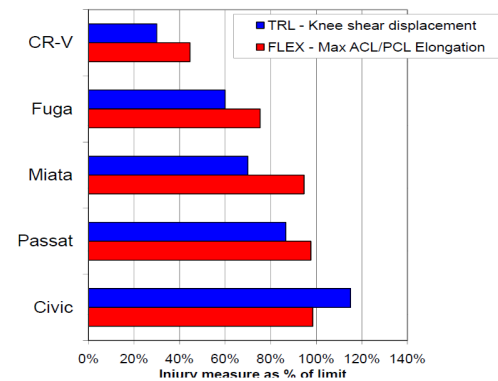
- Testing with a previous version of the Flex-GTR legform showed an inability of the legform to distinguish among vehicles that performed poorly
 - Measurements reached a limit (Mallory, 2010)



Fracture

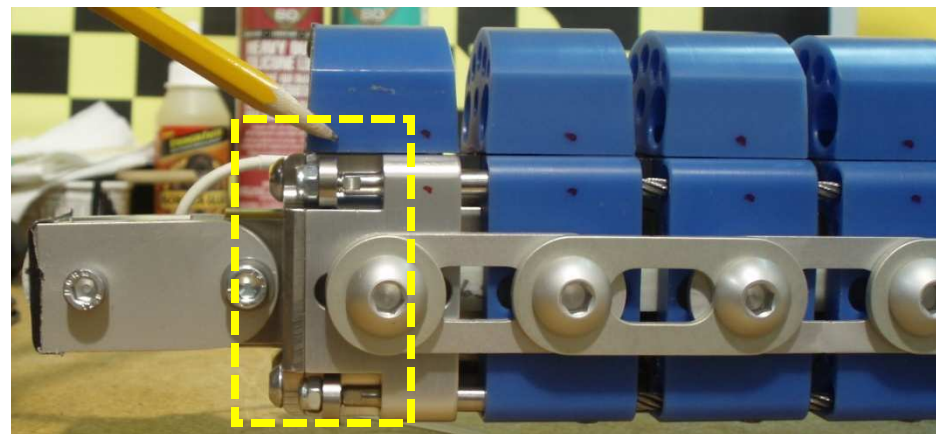


Bend



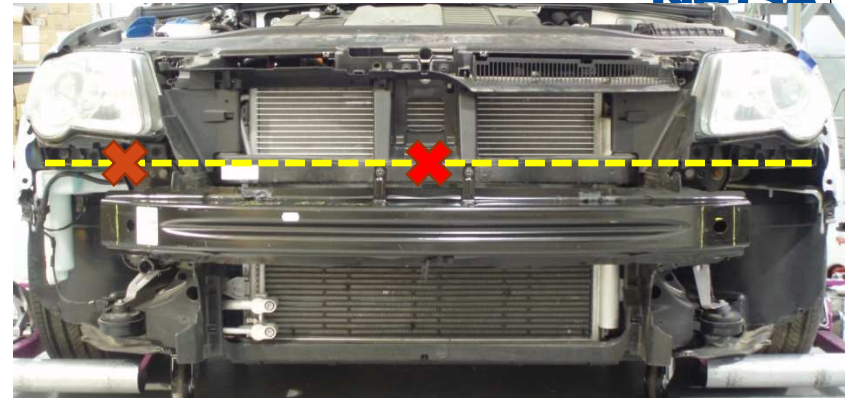
Shear

- Improvement in the current series of tests may be due to changes in Flex-GTR legform
 - Cable stop gap increase
 - Femur: 8 mm → 9.1 mm
 - Tibia: 9 mm → 10.3 mm

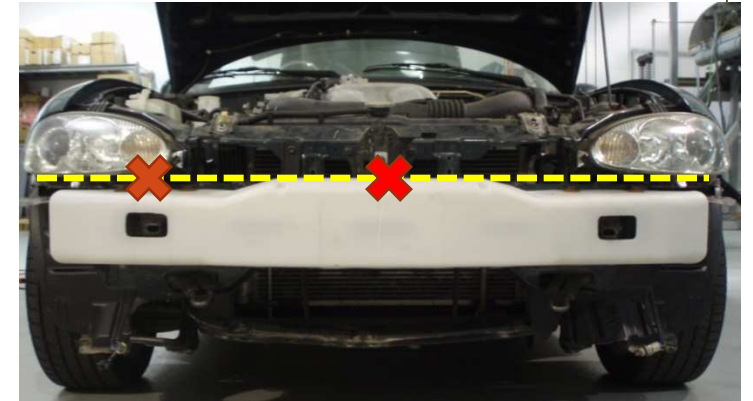


- Three additional tests performed on the centers of the three passenger cars

Volkswagen Passat



Mazda Miata



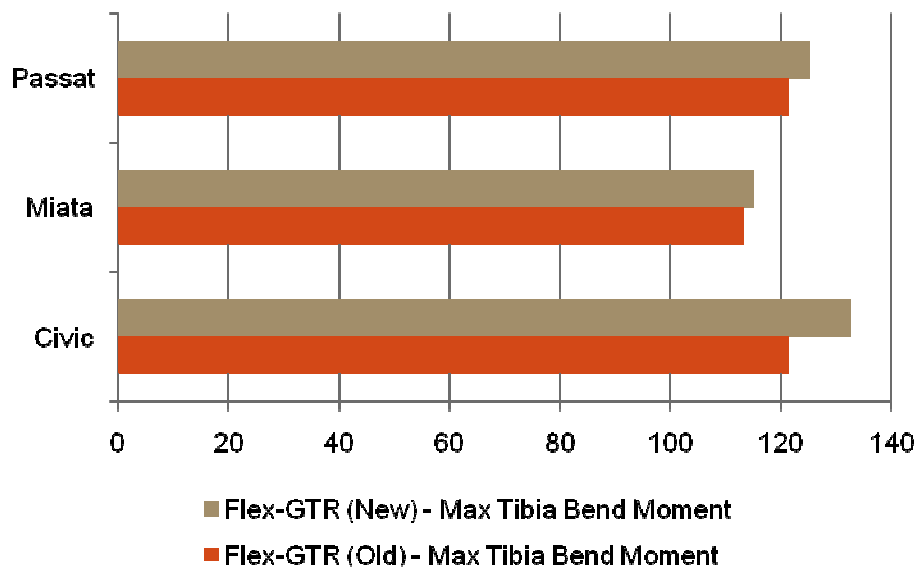
Honda Civic



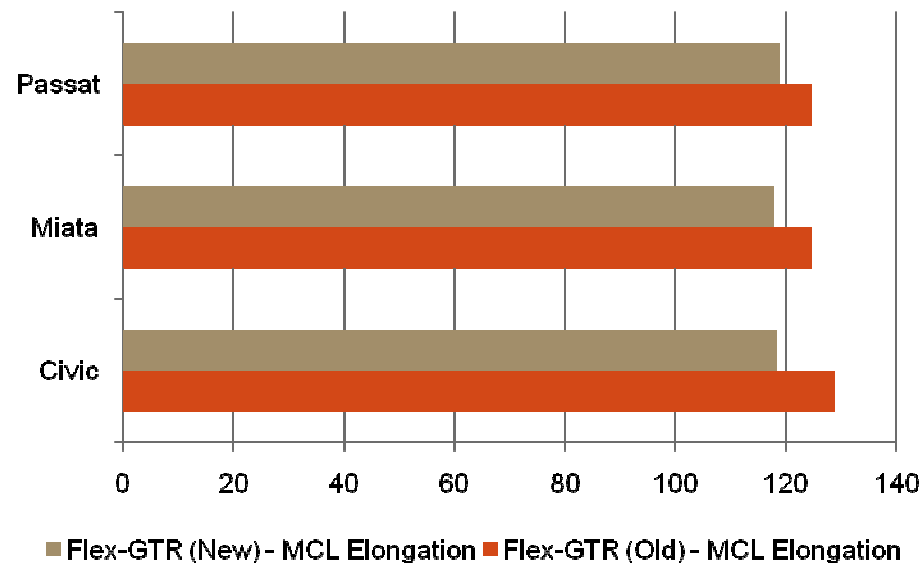
Comparison of Old and New Flex-GTR Data – Center Impacts



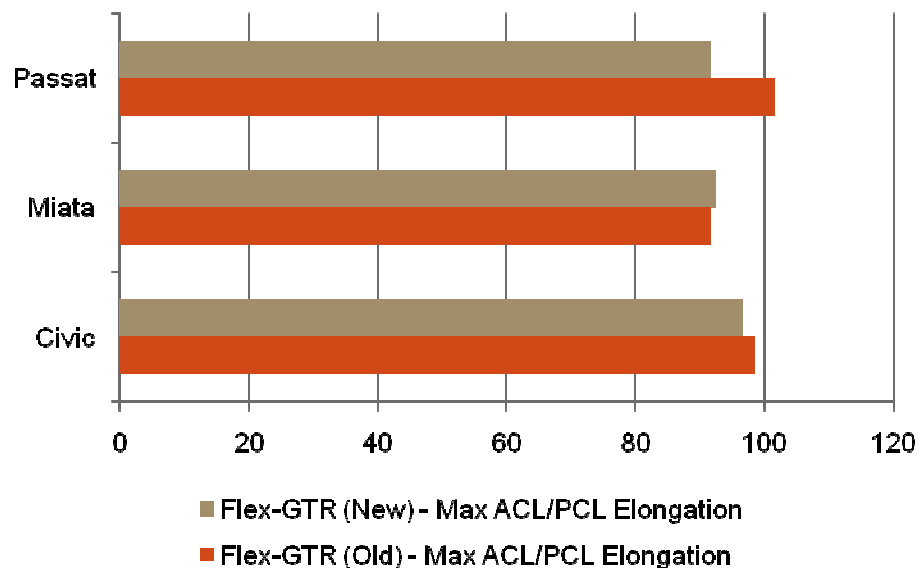
Fracture Measures



Bending Injury Measures



Shear Injury Measures



Summary of Findings

- The Flex-GTR measures lower values than the TRL legform
- The current Flex-GTR seems to be able to distinguish differences in relatively aggressive vehicle bumper designs better than the previous version
 - Topping out is not a concern with the current Flex-GTR
- Flex-GTR repeatability was not directly evaluated, but
 - Silverado Flex-GTR tests 1001 and 1002 showed similar numbers at the same impact location, which is promising

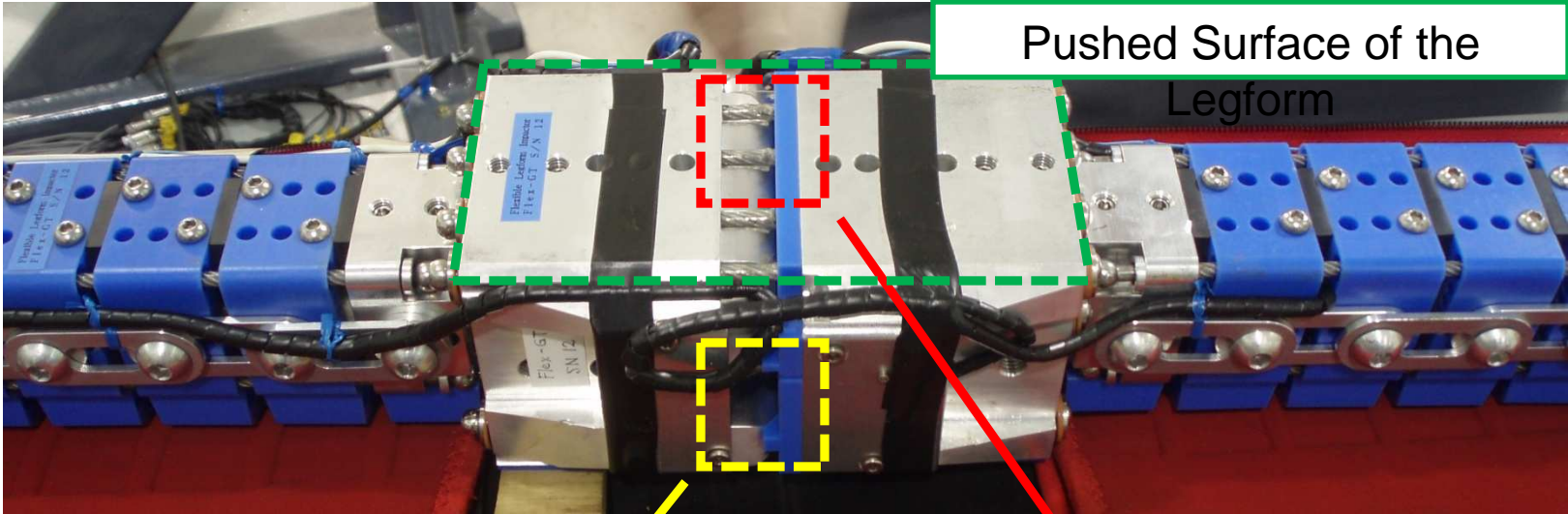
Flex-GTR Repeatability – Chevy Silverado

Injury Measurement		Injury Reference Value (FlexTEG)	Chevrolet Silverado	
Impact Location			Center	
			GTR (1001)	GTR (1002)
Femur Moment (Nm)	Femur 3 (Upper)	--*	73.67	77.28
	Femur 2 (Middle)		139.48	138.52
	Femur 1 (Lower)		252.05	245.58
Tibia Moment (Nm)	Tibia 1 (Upper)	340 Nm (380 Nm)	332.73	332.61
	Tibia 2 (Mid Upper)		311.07	319.53
	Tibia 3 (Mid Lower)		233.53	237.41
	Tibia 4 (Lower)		110.52	107.91
MCL Elongation (mm)		22 mm	--	22.28
ACL Elongation (mm)		13 mm	8	7.87
PCL Elongation (mm)		13 mm	5.41	5.61
LCL Elongation (mm)		--*	-4.16	-3.76
Tibia Acceleration (g)		--*	-59.21	-59.39
Velocity (m/s)		--*	11.055	11.137

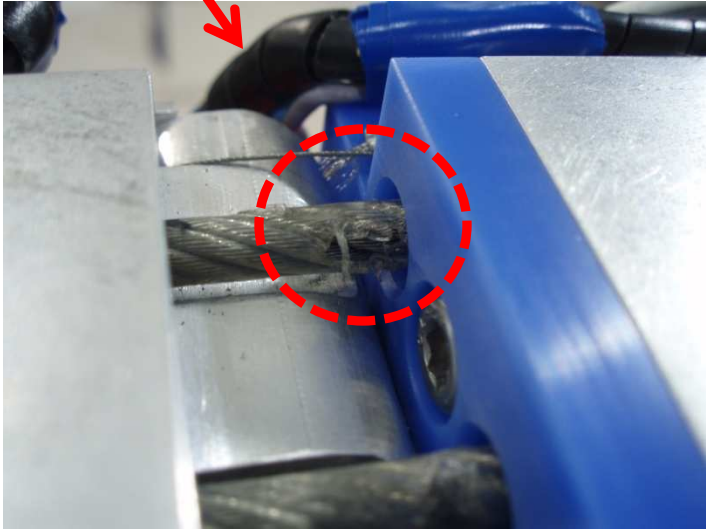
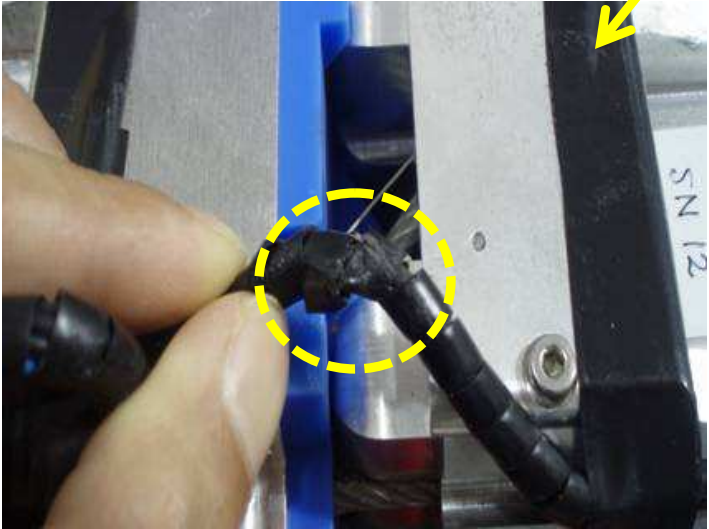
Summary of Findings

- The Flex-GTR measures lower values than the TRL legform
- The current Flex-GTR seems to be able to distinguish differences in relatively aggressive vehicle bumper designs better than the previous version
 - Topping out is not a concern with the current Flex-GTR
- Flex-GTR repeatability was not directly evaluated, but
 - Silverado Flex-GTR tests 1001 and 1002 showed similar numbers at the same impact location, which is promising
- The Flex-GTR was observed to be durable
 - Survived US vehicles
 - A majority of the issues that were observed were minor and repairable

Observations and Durability Assessment (Flex-GT)



Pushed Surface of the Legform

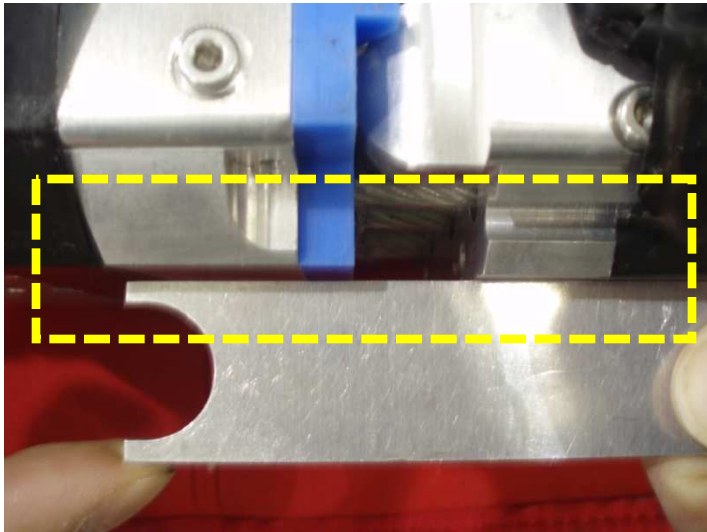
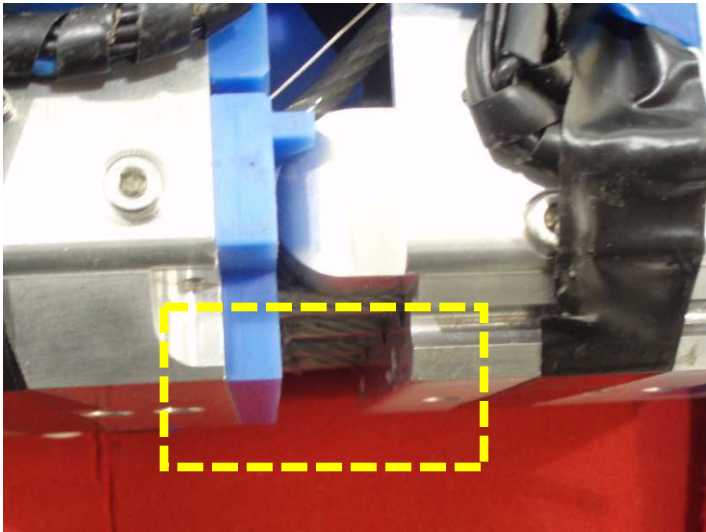
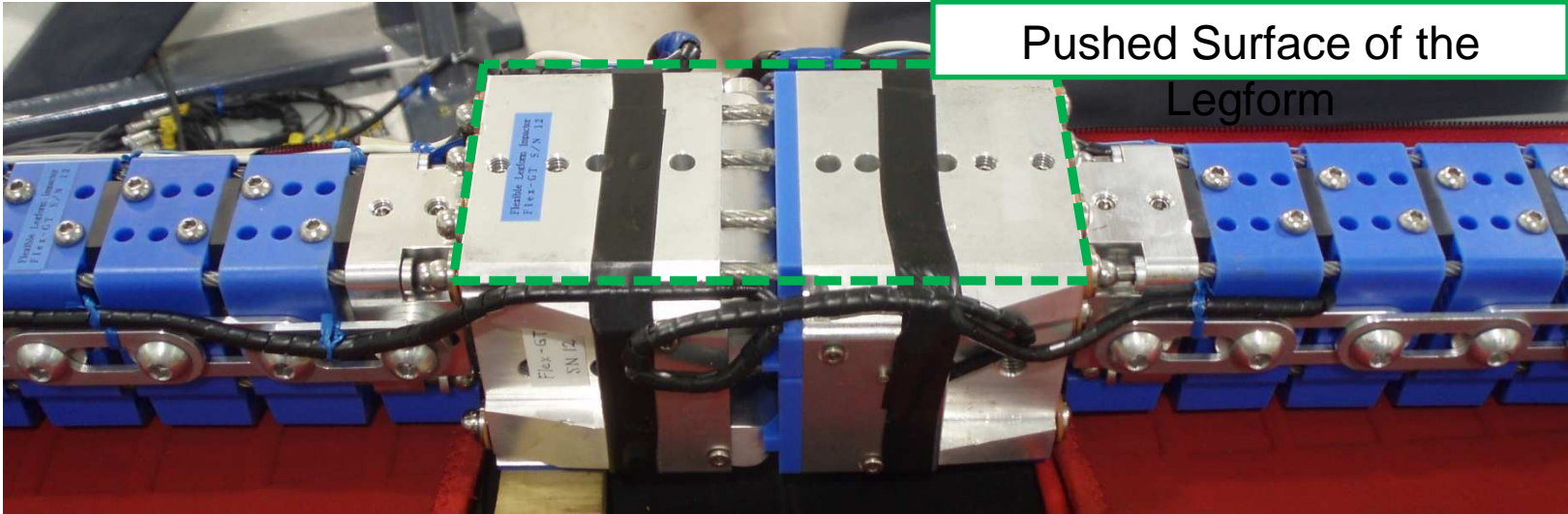


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Pinching of wires between blue tab and metal knee condyle

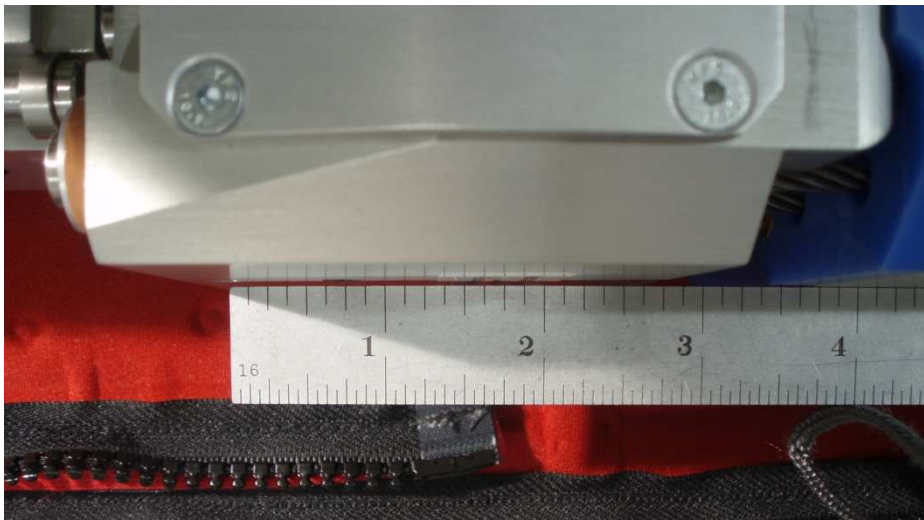
Wear and tear of plastic sheath around knee tension cables

Observations and Durability Assessment (Flex-GT)

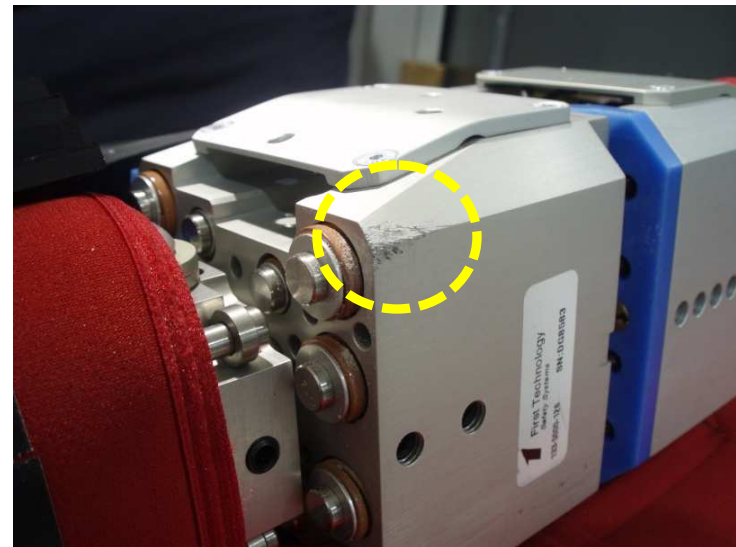


Tibia and Femur knee blocks are rotated/not flush with each other

Observations and Durability Assessment (Flex-GTR)



Misalignment of the knee after
Passat and Miata impacts

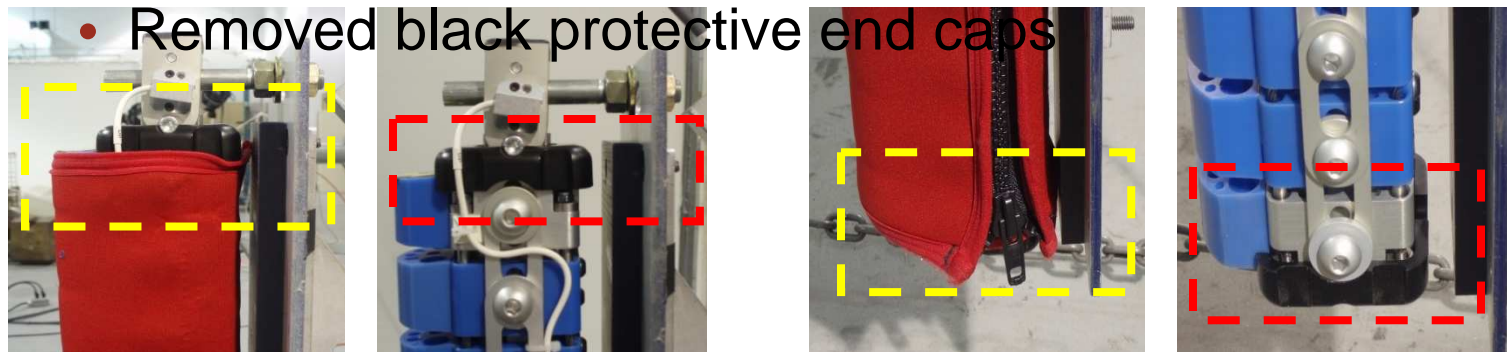


Tear in the neoprene skin and
scratches on the femur knee

block

Issues with Flex-GTR

- Needed to modify the legform in order for its flight to be within GTR tolerances for forward pitch (specific to the VRTC launch system)



- Konosu-san (JARI) informed us that they cut out notches at the top and bottom of the launch plate to accommodate for the end caps
- Femur strain gauge #2 (middle gauge)
 - Broken gauge/wire
 - Still being investigated

Summary of Findings

- Durability:
 - The Flex-GTR seems to be able to distinguish differences in relatively aggressive vehicle bumper designs better than the previous version
 - Flex-GTR repeatability was not directly evaluated, but
 - Silverado Flex-GTR tests 1001 and 1002 showed similar numbers at the same impact location, which is promising
 - The Flex-GTR was observed to be durable
 - Survived US vehicles
 - A majority of the issues that were observed were minor and repairable

Summary of Findings

- Injury criteria:
 - The Flex-GTR measures lower values than the TRL legform
 - Injury results were not consistent with previous testing:
 - Previous study has shown that it's rare to injure the ACL or PCL without injuring MCL. However, in the VW and Honda Civic tests, we observed ACL elongation that exceeded the injury criteria before the MCL exceeding injury criterion.
 - The findings raise concerns on whether the Flex GTR is properly modeling the impact or that the injury criteria are appropriate

Conclusion

- Flex-GTR legform is found to be durable
- Additional research and testing needed to address the injury criteria concerns
- Currently, more world fleet data is needed
- Different evaluation criteria may result in different counter-measures (design and cost benefit)

Thank you