Updates on THOR-50M Ongoing Research

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AGENDA

1. Manufacturing Reproducibility
2. Alternative Shoulder Design
3. Lumbar Flex Joint Durometer

Manufacturing Reproducibility

Manufacturing Reproducibility

Purpose

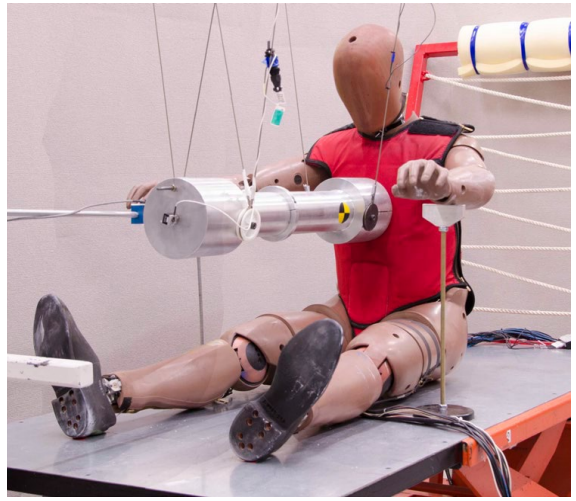
- Determine reproducibility of manufacturing

Methods

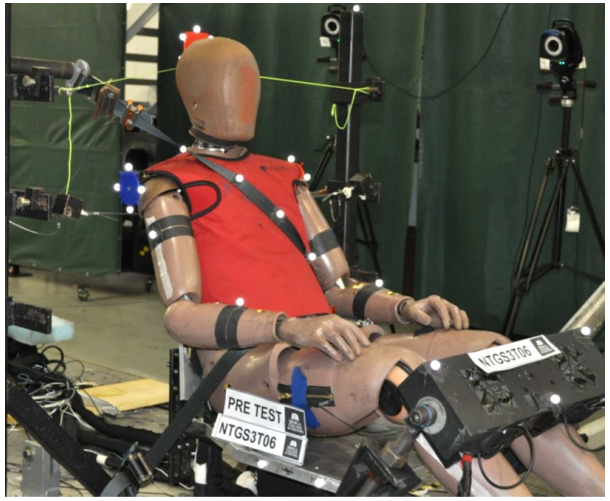
- Acquire ATDs from multiple manufacturers
- Obtain feedback from manufacturers on NHTSA specifications
- Evaluate performance of ATDs

Manufacturing Reproducibility – Evaluation

- Inspect ATDs against established drawing package



- Evaluate the performance of ATDs
  - Qualification testing
  - Durability testing
  - Sled testing in simplified environment
    - Gold Standard



Docket ID NHTSA-2019-0106 NHTSA Crashworthiness Research – THOR-50M Documentation

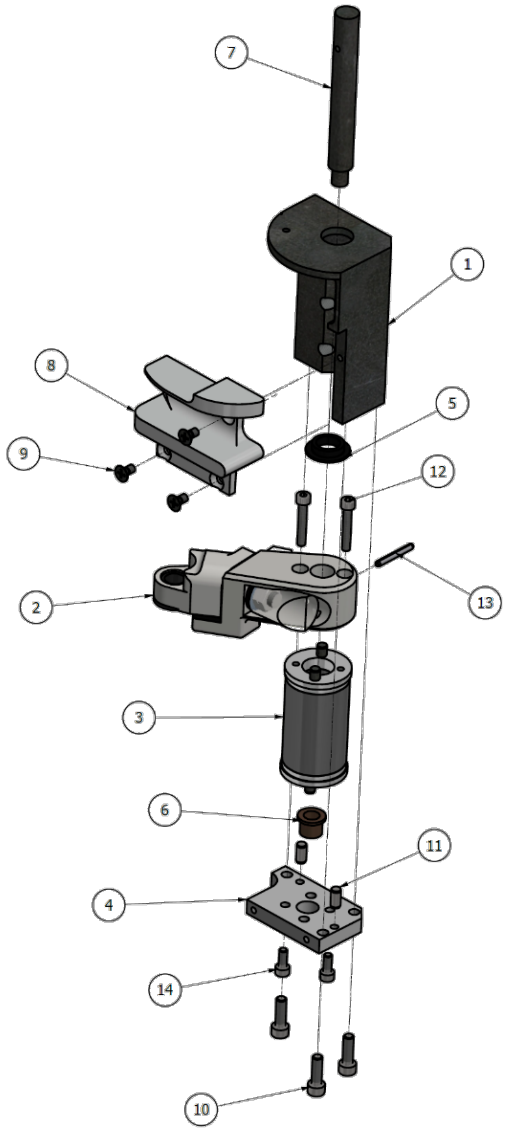
Shaw, G., Parent, D., Purtsezov, S., Lessley, D., Crandall, J., Kent, R., Guillemot, H., Ridella, S., Takhounts, E., Martin, P. (2009). Impact response of restrained PMHS in frontal sled tests: skeletal deformation patterns under seat belt loading. Stapp Car Crash Journal, Vol 53, pp 1-48

Alternative Shoulder Design

Shoulder

Purpose

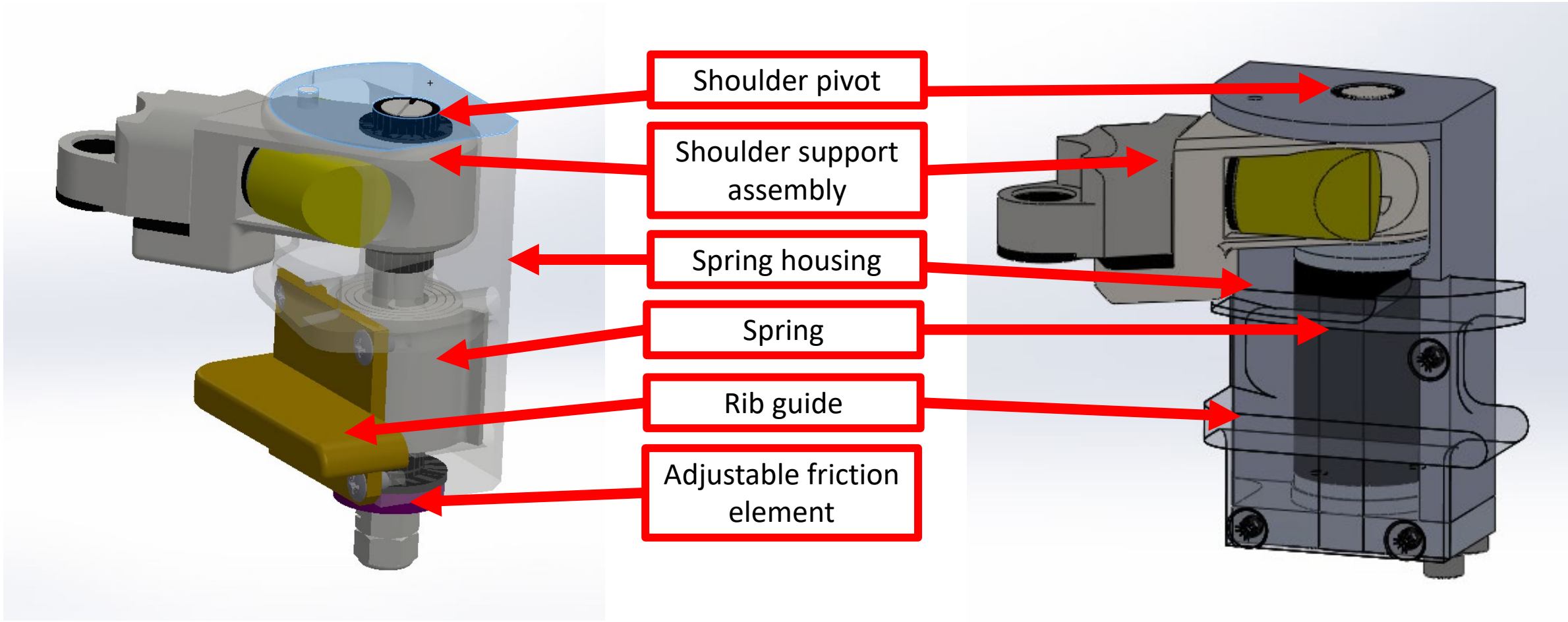
Design an alternative shoulder for the THOR-50M, taking care not to infringe on any current U.S. patents or patent applications



Process of Evaluation

- Quasi-static
- Qualification
- Biofidelity
- Sled

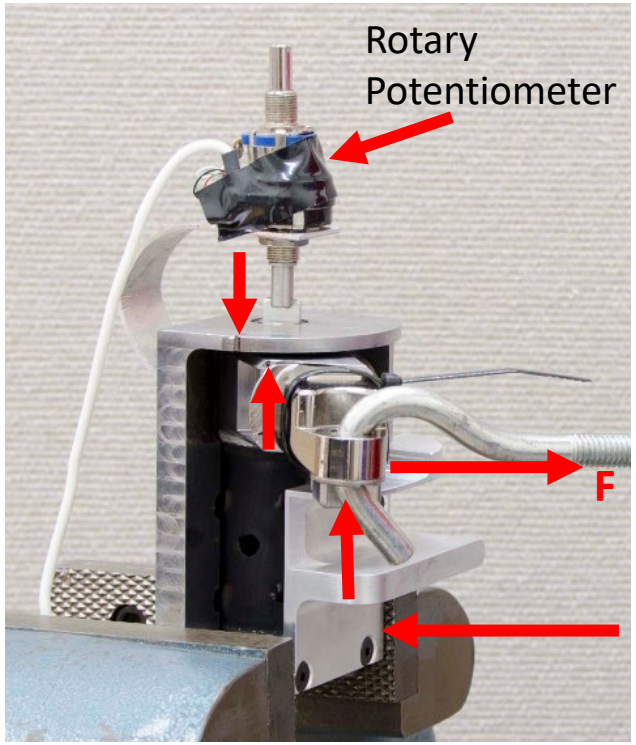
Shoulder - Design

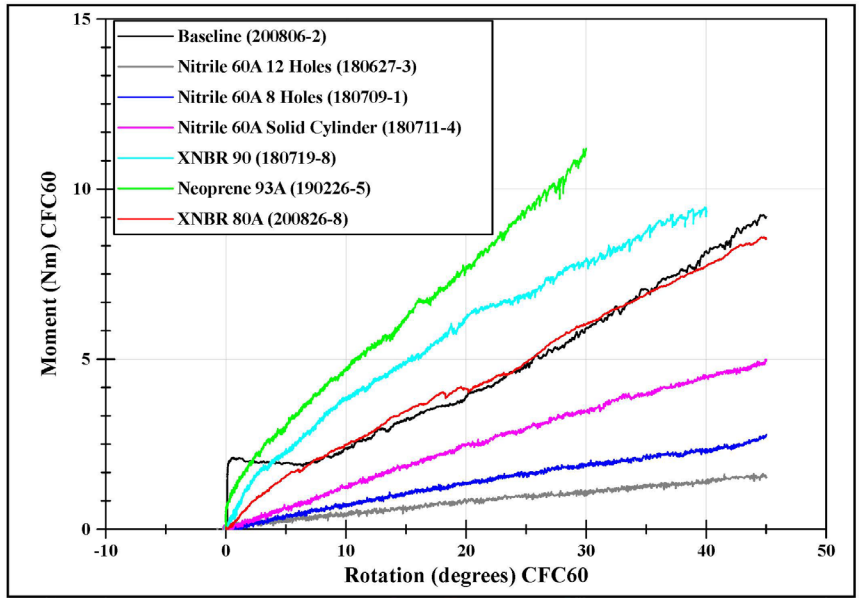


Baseline shoulder

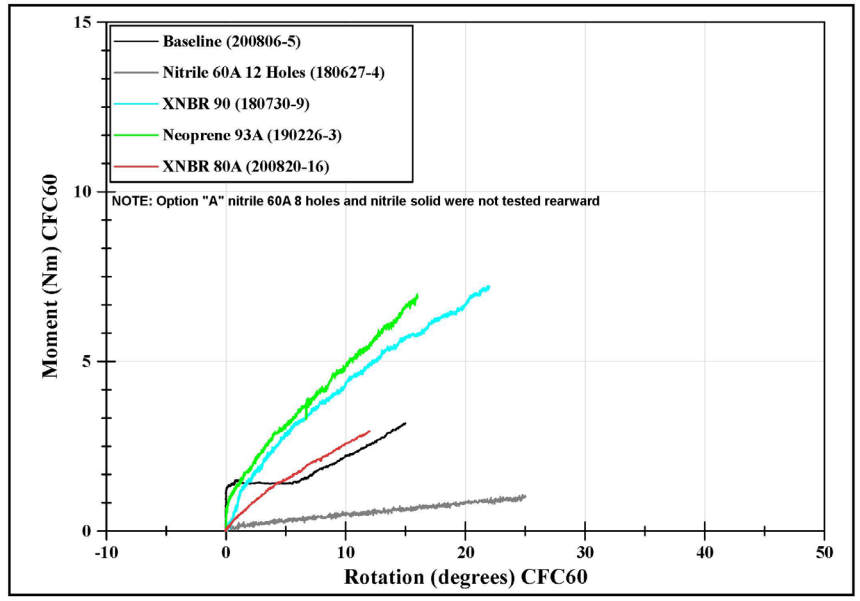
Alternative shoulder

Shoulder – Quasi-static Response





Forward Rotation



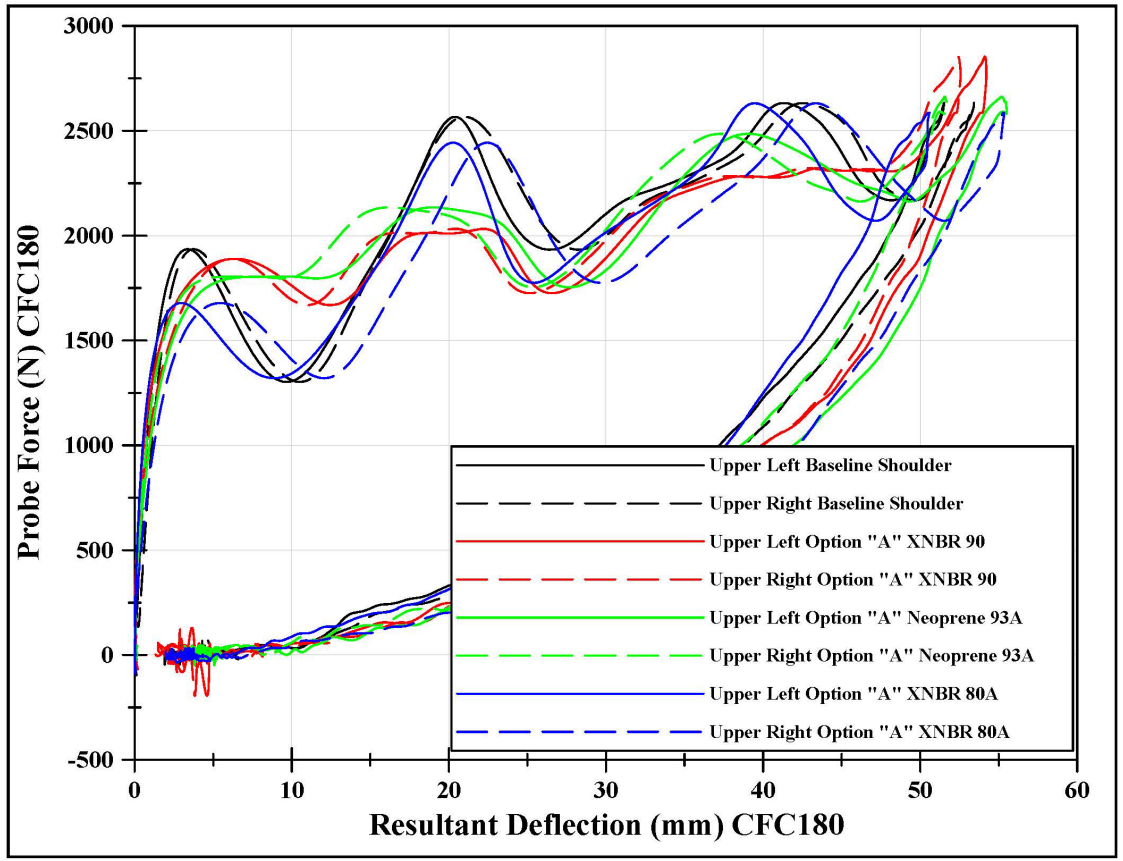
Rearward Rotation

- Test multiple variants
- Determine which variant most closely matches the baseline

Direction	Test	Stiffness (Nm/deg)	R^2	% Diff from Baseline
Forward	Baseline (n=9)	0.1957		
	XNBR80A (n=1)	0.1918	0.996	0.4%
Rearward	Baseline (n=9)	0.1850		
	XNBR80A (n=1)	0.2091	0.9941	2.4%

Shoulder – Qualification Response

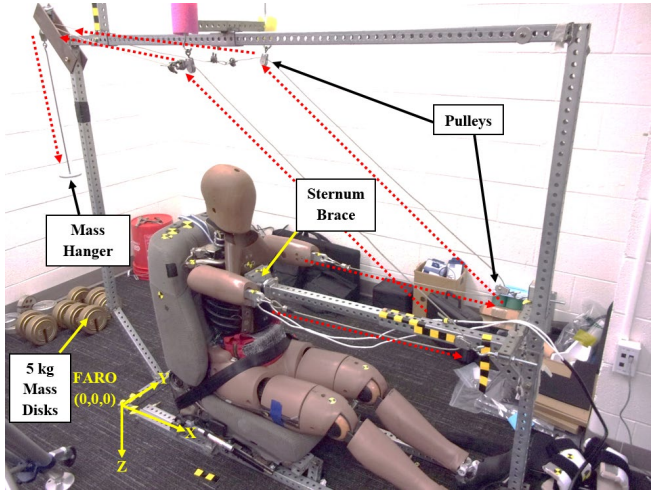
- All variants passed qualification testing



Parameter	Units	Specification		Baseline	XNBR 80A
		Min.	Max.	200915-2	200924-6
Impact Velocity	m/s	4.25	4.35	4.32	4.31
Peak Probe Force	N		3039	2633	2630
Peak Upper Left Resultant Deflection	mm	48.3	59.0	51.5	50.6
Peak Upper Right Resultant Deflection	mm			53.4	55.3
Difference Between Peak Left & Right Resultant Deflections	mm		< 5.0	1.9	4.7
Force at Left Peak Resultant Deflection	N	2409	2944	2633	2586
Force at Right Peak Resultant Deflection				2628	2582

Shoulder – Biofidelity Response

- Only the baseline and XNBR 80A shoulders were tested
- Tornvall tests performed at: 90°, 135°, and 170°
  - X and Z displacements were evaluated with NHTSA's BRS
- Alternative shoulder performed similarly to the baseline



BRS Scores	
Baseline Shoulder	**XNBR 80A Shoulder**
1.43	1.37

- Score represents multiples of SDs
- Lower score is better
- Score <2 indicates good biofidelity

Tornvall, F.V., Holmqvist, K., Martinsson, J., Davidsson, J., (2005). Comparison of shoulder range-of-motion and stiffness between volunteers, Hybrid III and THOR Alpha in static frontal impact loading, International Journal of Crashworthiness, 10:2, 151-160, DOI: 10.1533/ijcr.2005.0334

Hagedorn, A., Stammen J., Ramachandra, R., Rhule, H., et al.. Biofidelity Evaluation of THOR-50M in Rear-Facing Seating Configurations Using an Updated Biofidelity Ranking System, *SAE Int. J. Trans. Safety* 10(2):2022, doi:10.4271/09-10-02-0013.

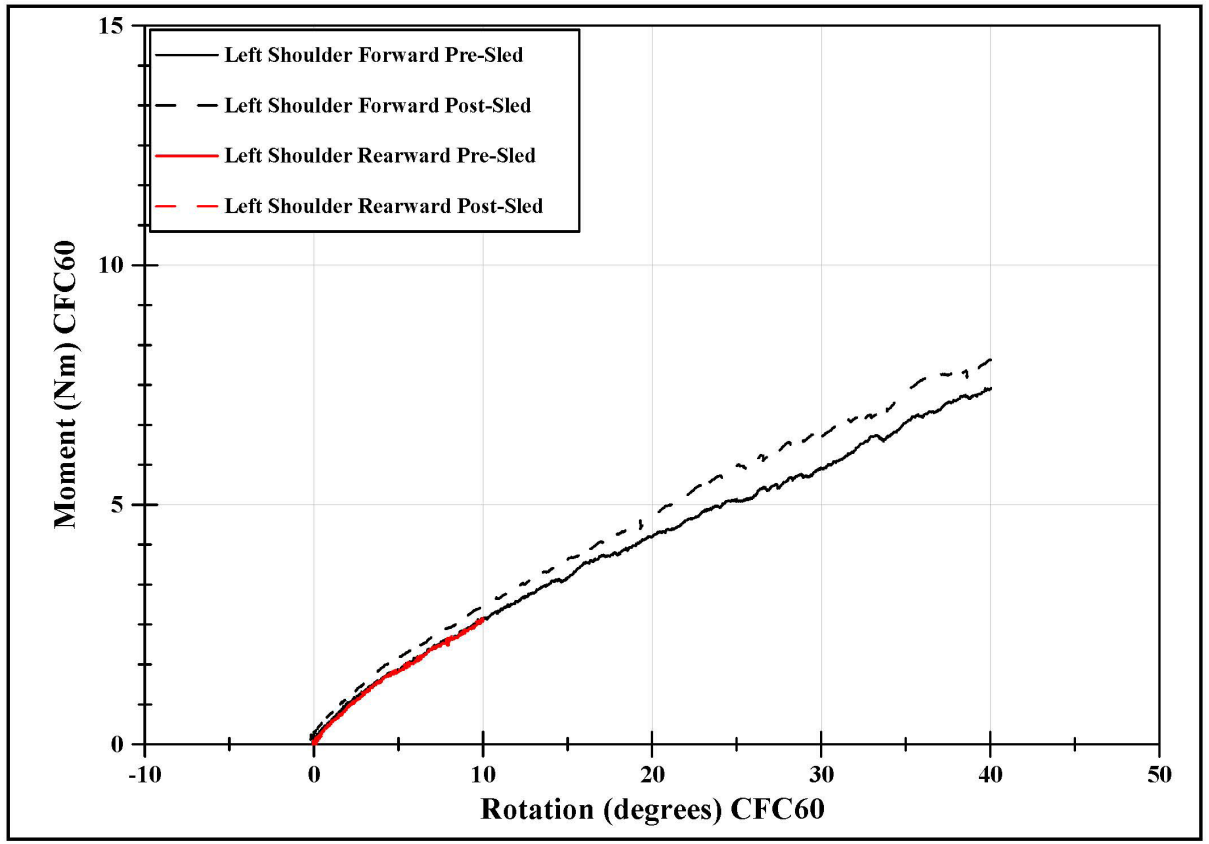
Shoulder – Sled Response

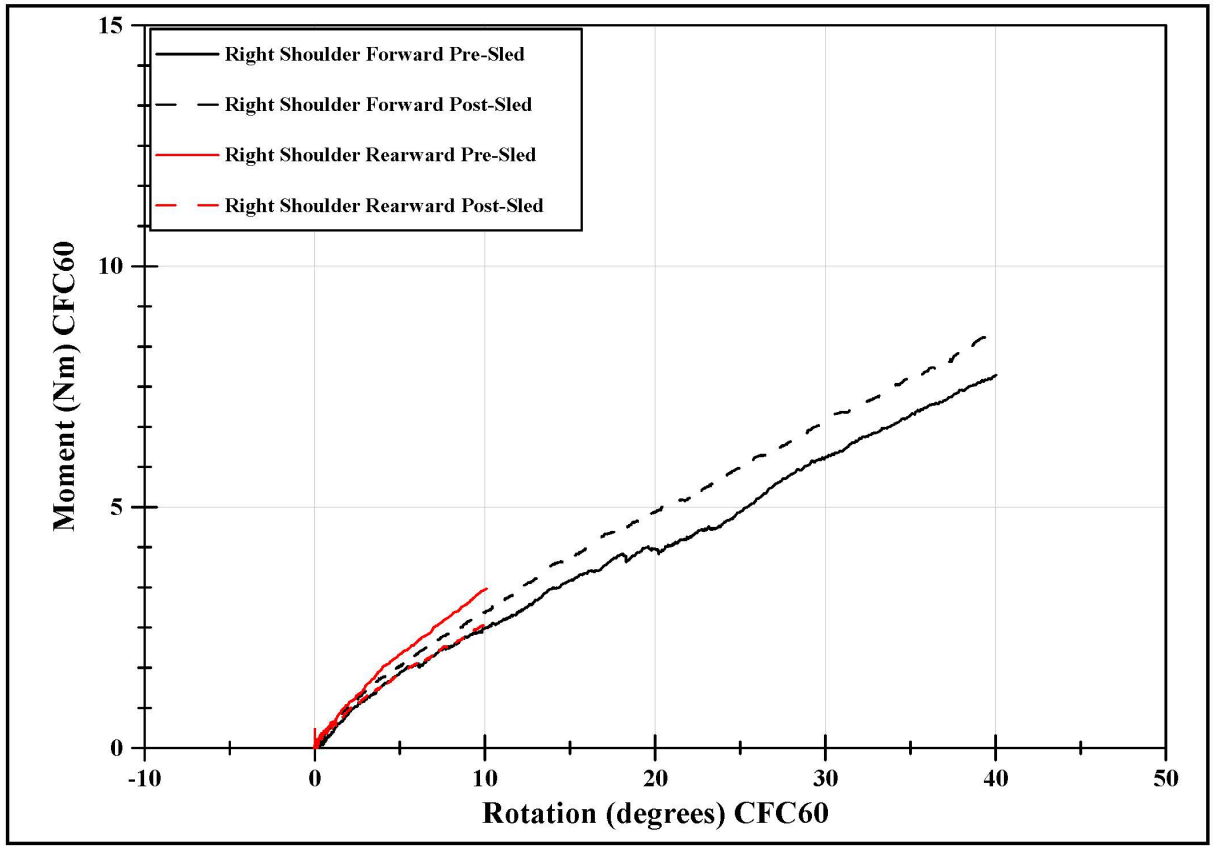
- Modified 2017 Mazda CX3 sled buck
- Pulse approximately NCAP CX3 test

Sled Test Responses		Test	Head Excursion (mm)	UL Thx. Res. Defl.	UR Thx. Res. Defl.	R Abd. Res. Defl.
Driver	XNBR 80A Shoulder (n=3)	Avg.	548		45.3	45.0
		Std. Dev.	5		1.6	0.6
		CV	1%		4%	1%
	Baseline Shoulder (n=3)	Avg.	550		48.6	47.8
		Std. Dev.	7		0.6	1.0
		CV	1%		1%	2%
	Combined Shoulders (n=6)	Avg.	549		47.2	46.4
		Std. Dev.	5		2.0	1.7
		CV	1%		4%	4%
Passenger	XNBR 80A Shoulder (n=3)	Avg.	740	39.3		39.5
		Std. Dev.	35	2.6		2.3
		CV	5%	7%		6%
	Baseline Shoulder (n=3)	Avg.	777	45.1		40.3
		Std. Dev.	35	2.8		1.7
		CV	5%	6%		4%
	Combined Shoulders (n=6)	Avg.	759	42.2		39.9
		Std. Dev.	37	4.0		1.9
		CV	5%	10%		5%

Shoulder – Durability

- Quasi-static tests were performed before and after sled tests





Lumbar Flex Joint Durometer

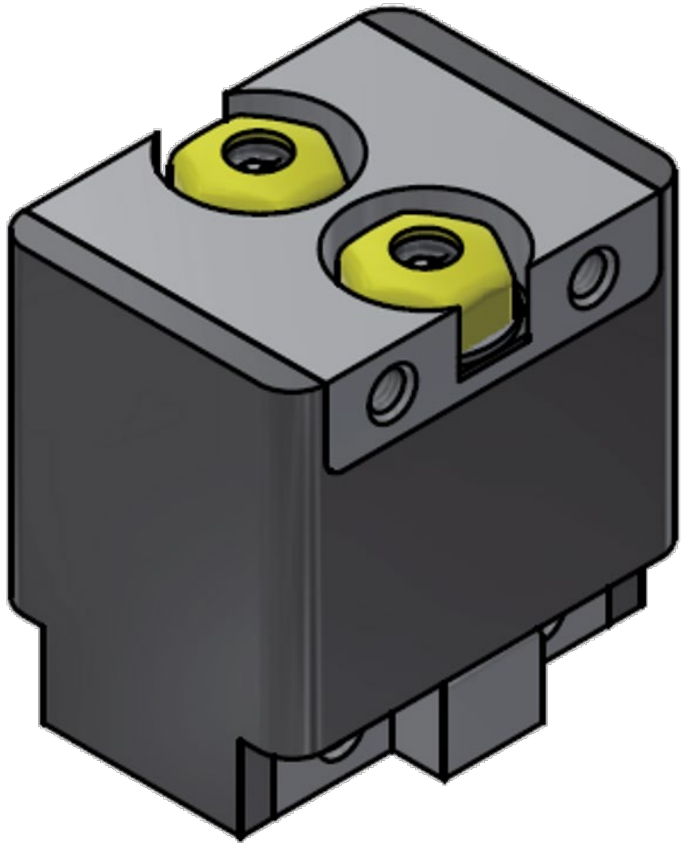
Lumbar Flex Joint Durometer

Purpose

Quantify performance differences between lumbar spine flex joints with various rubber durometers

Methods

- Perform qualification tests
- Perform isolated component tests



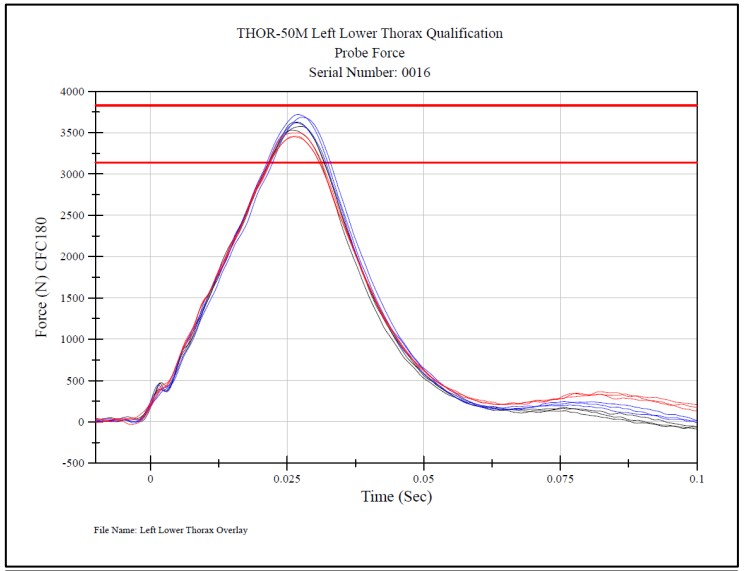
Lumbar Flex Joint Durometer – Qual.

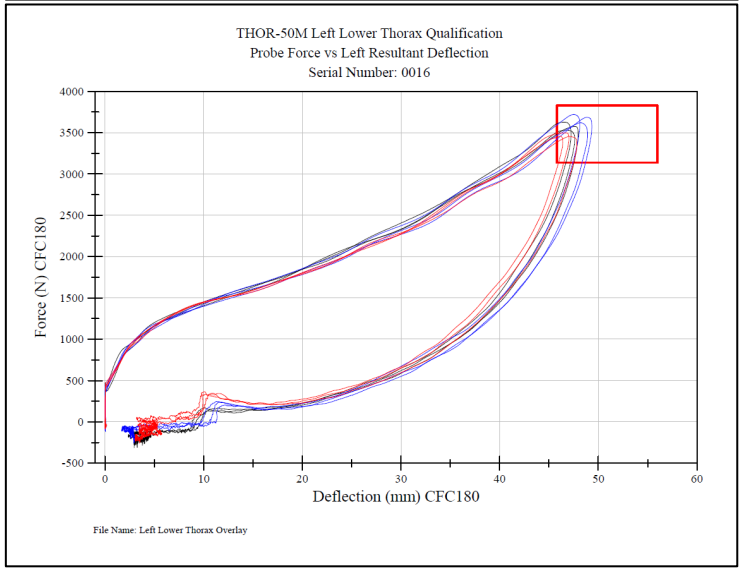
Conditions

- One THOR-50M ATD
- Shore A spine durometers: 65, 75, 85
  - Drawing specification is Shore A 75±2
- Qualification test modes
  - Head, upper thorax, lower left/right thorax, and lower abdomen

Preliminary Results

- ATD positioning is affected by the durometer
- All spines produced passing test results





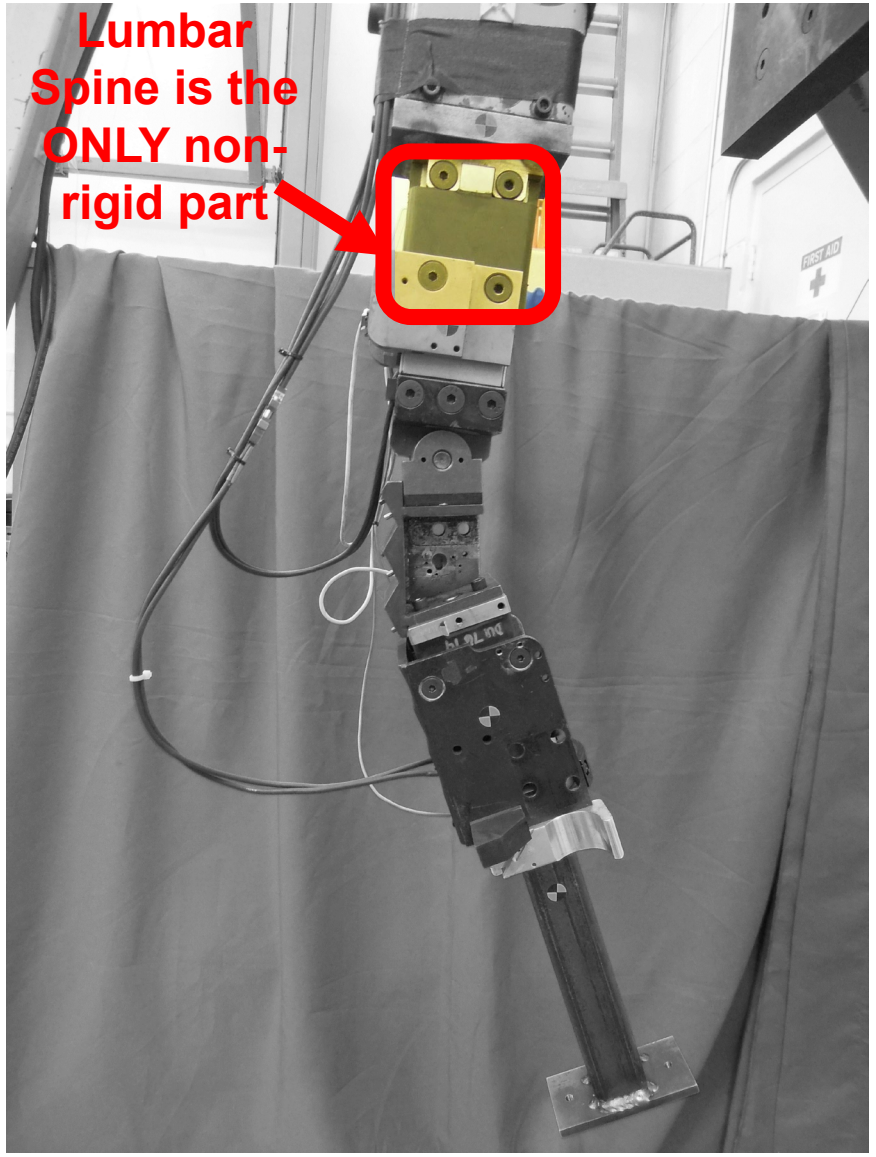
Lumbar Flex Joint Durometer – Isolated

Objective

- Determine response differences to better define material properties for FE models

Method

- Assemble THOR-50M spine with ballast and all rigid components except for the lumbar spine flex joint
- Perform component tests on pendulum



Thank you!

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