FHWA/NHTSA National Crash Analysis Center
The George Washington University

Analysis of Compatibility Metrics in Frontal Collisions

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Presentation Outline

Finite element modeling approach was used to evaluate compatibility metrics in rigid barrier tests

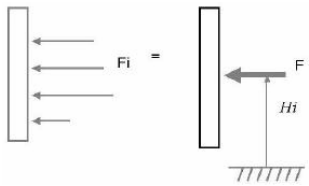
1. **Compatibility metrics review**
2. **Vehicle models used**
3. **Load cell resolution study ***
4. **Robustness of the compatibility metrics ****
   - Affect of vehicle mass on these metrics
   - Affect of vehicle speed on these metrics

** SAE paper 2007-01-1182*

*** ESV paper 07-0188*

Compatibility Metrics

- **AHOF400 (geometry matching)**



$$HOF(d) = \frac{\sum_{i=1}^{n} F_i(d) H_i(d)}{\sum_{i=1}^{n} F_i(d)}$$

$$AHOF400 = \frac{\sum_{d=25mm}^{400mm} HOF(d) F(d)}{\sum_{d=25mm}^{400mm} F(d)}$$

$F_i(d)$ = force on a load cell, F(d) = total force on the wall at crush d.

- **KW400 (stiffness matching)**

F = average force on the wall over 25 to 400 mm of vehicle crush

$$\int_{25}^{400} F dx = \frac{1}{2} Kw400[(400)^2 - (25)^2]$$

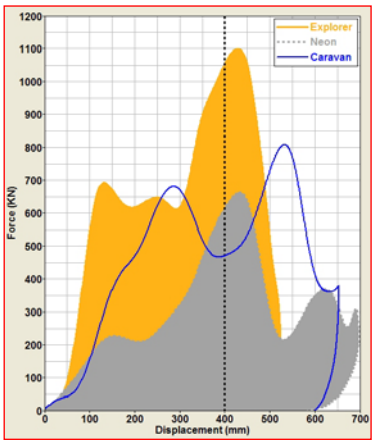
$$F(400-25) = \frac{1}{2} Kw400[(400)^2 - (25)^2]$$

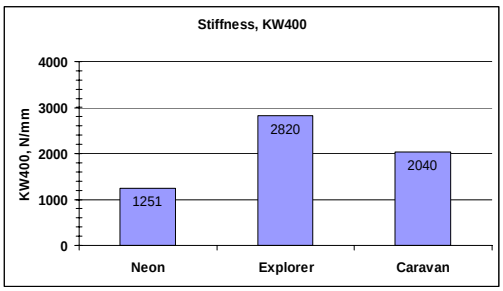
$$Kw400 = \frac{2F}{425}$$

Vehicle Models

- **FE models validated for a frontal NCAP test were chosen for this study**
  - Compact Car (1996 Dodge Neon)
  - SUV (2003 Ford Explorer)
  - Mini-Van (1997 Dodge Caravan)

KW400

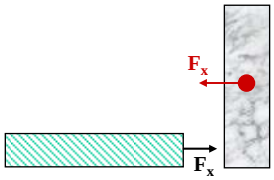




Load Cell Barrier Resolution Study

- **Motivation**

Make & Model	Year	NCAP Barrier (250x250 mm LC)		High Res. Barrier (125x125 mm LC)		AHOF400 difference (mm)
		Test No	AHOF400 (mm)	Test No	AHOF400 (mm)	
Chevy Silverado	2003	4472	476	5711	512	36
Ford Focus	2002	4080	431	5712	461	30
Honda Odyssey	2005	5273	450	5714	457	7

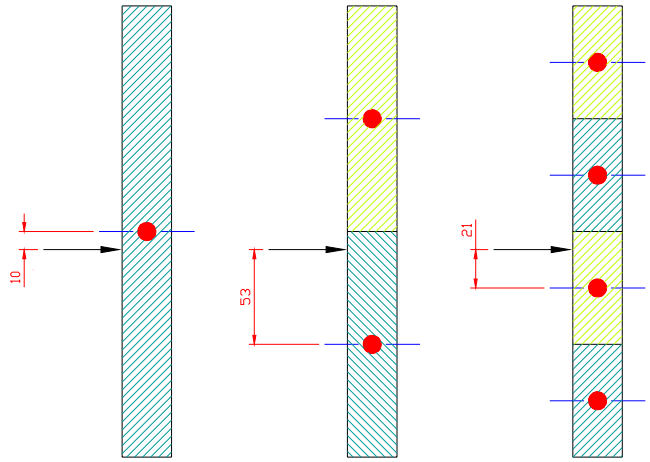


Single-axis Load cell

- ⇨ Theoretically, the error in HOF measurement could be as high as ½ the load cell size in a single-axis LC
- ⇨ Allowable error, 10% of the Part 581 zone = ±10 mm

Load Cell Barrier Resolution Study

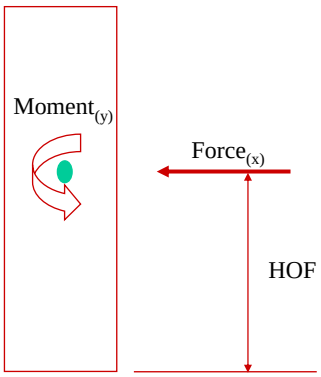
- Increasing load cell resolution may not always improve accuracy of HOF measurement

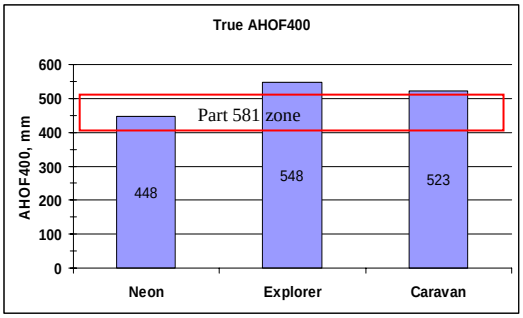


True AHOF400

- True AHOF400 is derived from an infinite resolution load cell wall
- Moment about the y-axis (My) is needed to calculate the exact height of force application

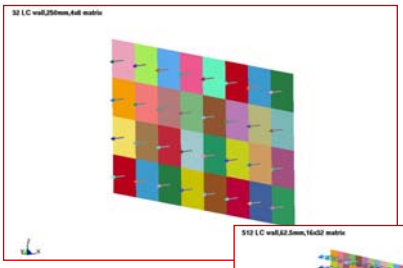
$$HOF = \frac{Moment_{(y)}}{Force_{(x)}}$$

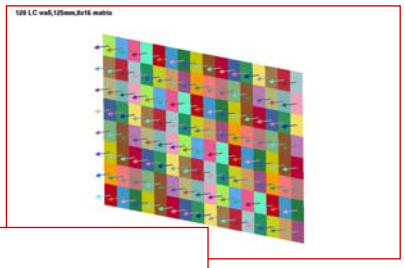


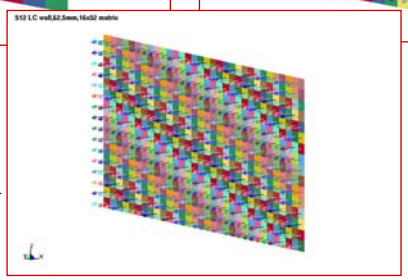


Load Cell Barrier Resolution Study

- 4x8, 250 mm load cells
- 8x16, 125 mm load cells







- 16x32, 62.5 mm load cells

Neon AHOF400

- Load cell barrier instrumented with <u>single-axis load cells (Fx only)</u>

	Load Cell Resolution									
	Infinite	4x8 array			8x16 array			16x32 array		
	Infinite	250 mm LC (Fx)			125 mm LC (Fx)			62.5 mm LC (Fx)		
Height from ground (mm)	True AHOF (mm)	Measured AHOF (mm)	Error (mm)	Error (%)	Measured AHOF (mm)	Error (mm)	Error (%)	Measured AHOF (mm)	Error (mm)	Error (%)
66	448	455	7	2%	451	3	1%	453	5	1%
66+25	448	468	20	5%	462	14	3%	449	1	0%
66+50	448	461	13	3%	448	0	0%	444	-4	1%
66+75	448	444	-4	1%	437	-11	2%	447	-1	0%
66+100	448	431	-17	4%	439	-9	2%	450	2	0%
66+125	448	447	-1	0%	451	3	1%	453	5	1%

- Acceptable alternatives
  - ⇨ Choose load cell barrier instrumented with 62.5x62.5 mm single axis LC's (total of 648 axial LC's)
  - ⇨ Choose load cell barrier instrumented with multi-axis LC's measuring F_X and M_Y

Explorer, AHOF400

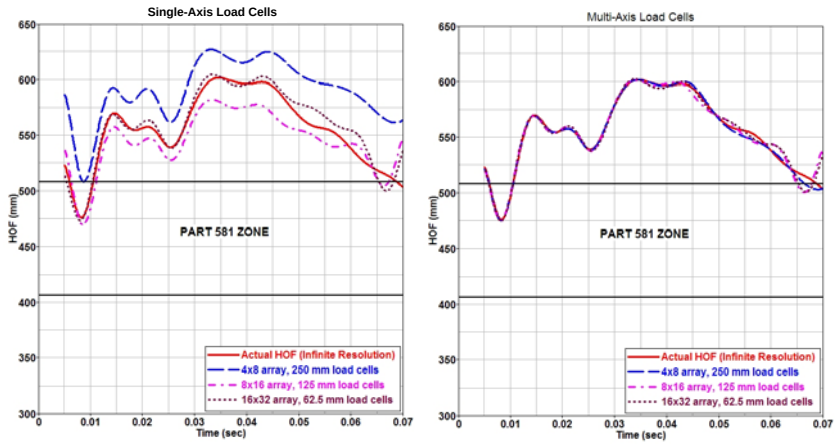
- **Load cell barrier instrumented with <u>single-axis load cells (Fx only)</u>**

	Load Cell Resolution									
	Infinite	4x8 array			8x16 array			16x32 array		
	Infinite	250 mm LC (Fx)			125 mm LC (Fx)			62.5 mm LC (Fx)		
Height from ground (mm)	True AHOF (mm)	Measured AHOF (mm)	Error (mm)	Error (%)	Measured AHOF (mm)	Error (mm)	Error (%)	Measured AHOF (mm)	Error (mm)	Error (%)
150	548	577	29	5%	532	-16	3%	544	-4	1%
150+25	548	576	28	5%	536	-12	2%	549	1	0%
150+50	548	589	41	8%	551	3	1%	549	1	0%
150+75	548	582	34	6%	557	9	2%	546	-2	0%
150+100	548	538	-10	2%	546	-2	0%	544	-4	1%
150+125	548	486	-62	11%	531	-17	3%	543	-5	1%

- **Acceptable alternatives**
  - ⇨ Choose load cell barrier instrumented with 62.5x62.5 mm single axis LC's (total of 648 axial LC's)
  - ⇨ Choose load cell barrier instrumented with multi-axis LC's measuring F_X and M_Y

Explorer HOF

- **Load cell barrier 175 mm above ground**



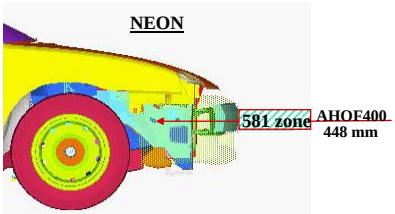
Caravan AHOF400

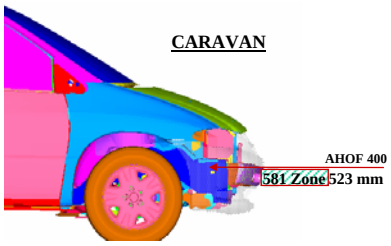
- **Load cell barrier instrumented with <u>single-axis load cells (Fx only)</u>**

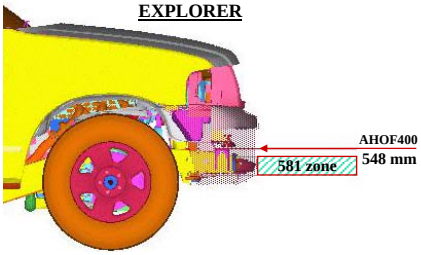
	Load Cell Resolution									
	Infinite	4x8 array			8x16 array			16x32 array		
	Infinite	250 mm LC (Fx)			125 mm LC (Fx)			62.5 mm LC (Fx)		
Height from ground (mm)	True AHOF (mm)	Measured AHOF (mm)	Error (mm)	Error (%)	Measured AHOF (mm)	Error (mm)	Error (%)	Measured AHOF (mm)	Error (mm)	Error (%)
66	523	469	-54	10%	510	-13	3%	524	1	0%
66+25	523	483	-40	8%	527	4	1%	521	-2	0%
66+50	523	503	-20	4%	530	7	1%	519	-4	1%
66+75	523	525	2	0%	518	-5	1%	518	-5	1%
66+100	523	544	21	4%	519	-4	1%	527	4	1%
66+125	523	552	29	5%	511	-12	2%	525	2	0%

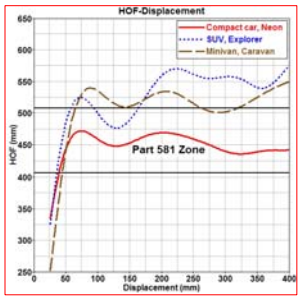
- **Acceptable alternatives**
  - ⇨ Choose load cell barrier instrumented with 62.5x62.5 mm single axis LC's (total of 648 axial LC's)
  - ⇨ Choose load cell barrier instrumented with multi-axis LC's measuring F_X and M_Y

True AHOF400 comparison



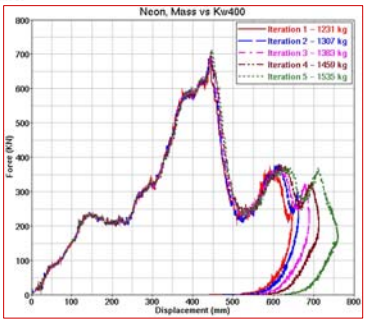


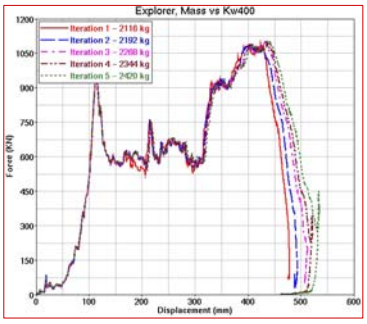




Robustness of
Compatibility Metrics

Influence of mass, Kw400





	UDW (kg)	Number of occupants	Total Mass (kg)	Kw400 (N/mm)
Dodge Neon	1155	1	1231	1261.2
		2	1307	1260.1
		3	1383	1249.2
		4	1459	1247.9
		5	1535	1250.9

	UDW (kg)	Number of occupants	Total Mass (kg)	Kw400 (N/mm)
Ford Explorer	2040	1	2116	2828.2
		2	2192	2827.8
		3	2268	2820.7
		4	2344	2812.9
		5	2420	2800.1

Added mass showed no effect on Kw400

Influence of mass, AHOF400

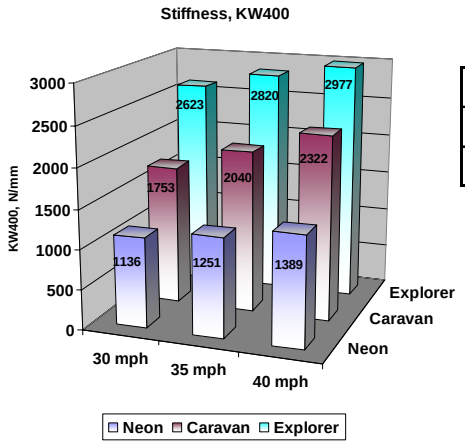
- ⇨ Similar mass increments as in the KW400 study were considered
- ⇨ Change in ride height due to mass increase was not considered

	UDW (kg)	Number of occupants	Total Mass (kg)	AHOF400 (mm)
Dodge Neon	1155	1	1231	447.58
		2	1307	447.83
		3	1383	447.97
		4	1459	447.92
		5	1535	448.13

	UDW (kg)	Number of occupants	Total Mass (kg)	AHOF400 (mm)
Ford Explorer	2040	1	2116	549.39
		2	2192	548.22
		3	2268	547.49
		4	2344	547.39
		5	2420	546.47

Added mass showed no effect on AHOF400

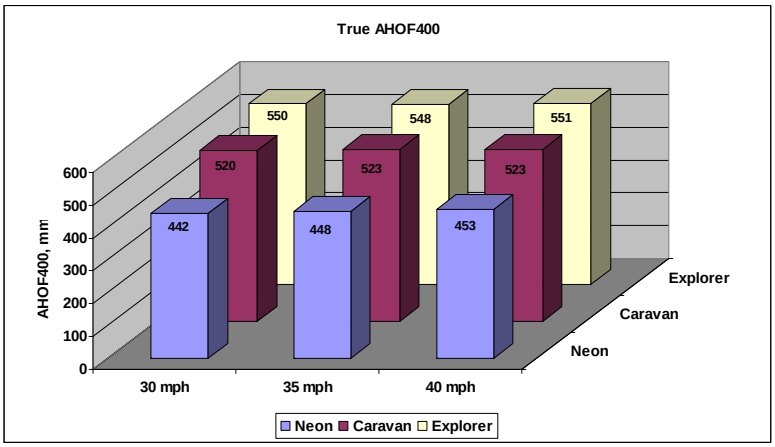
Influence of impact velocity, Kw400



KW400 Ratios	30 mph	35 mph	40 mph
Caravan/Neon	1.54	1.63	1.67
Explorer/Neon	2.31	2.25	2.14

Kw400 increases with impact speed, but Kw400 ratio remained nearly constant for the two vehicle pairs

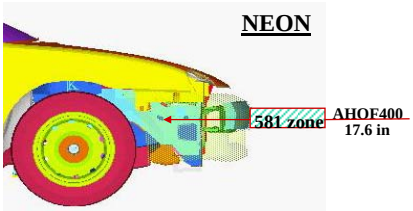
Influence of impact velocity, AHOF400

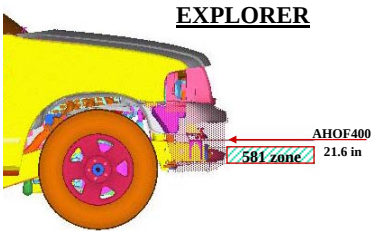


Impact speed showed no effect on AHOF400

Ongoing Research

Option 1 LTV to compact car

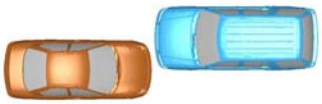




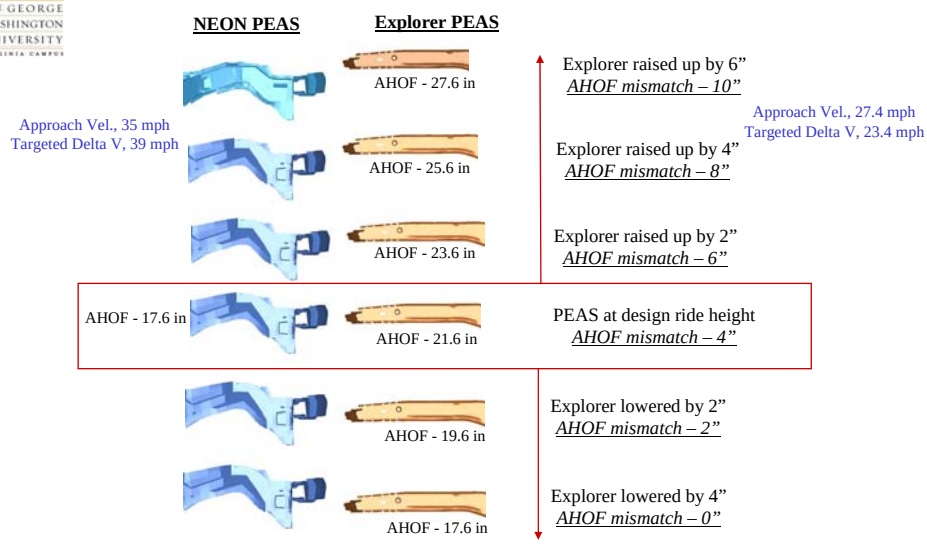
- **Vertical alignment study**

Full overlap

50% overlap

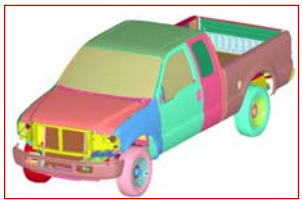


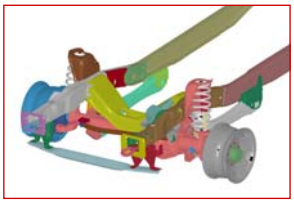
Vertical Alignment



Option 2 LTV Model Development, Ford F-250

VIN 1FTSX21516EA73254, 2006 SD F250 4x4 SUPERCAB





- **Detailed model, can be used for all impact scenarios**
- **Material data derived from coupon testing**
- **Frontal 35 mph high resolution rigid barrier test verification complete**
- **25 mph override barrier test verification is ongoing**

Number of Parts	- 738
Number of Nodes	- 734078
Number of Shells	- 694438
Number of Beams	- 2298
Number of Solids	- 25903
Number of Elements	- 722684

Acknowledgement

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