FMH, Methodology for Better Understanding of Kinematic-Stiffness Coupling Behavior

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Canoo's mission is to bring EVs to Everyone.

Canoo has teams in Arkansas, Oklahoma, Texas, Michigan & California

Canoo Delivers Crew Transportation Vehicles To Nasa For Artemis Mssions

Introduction

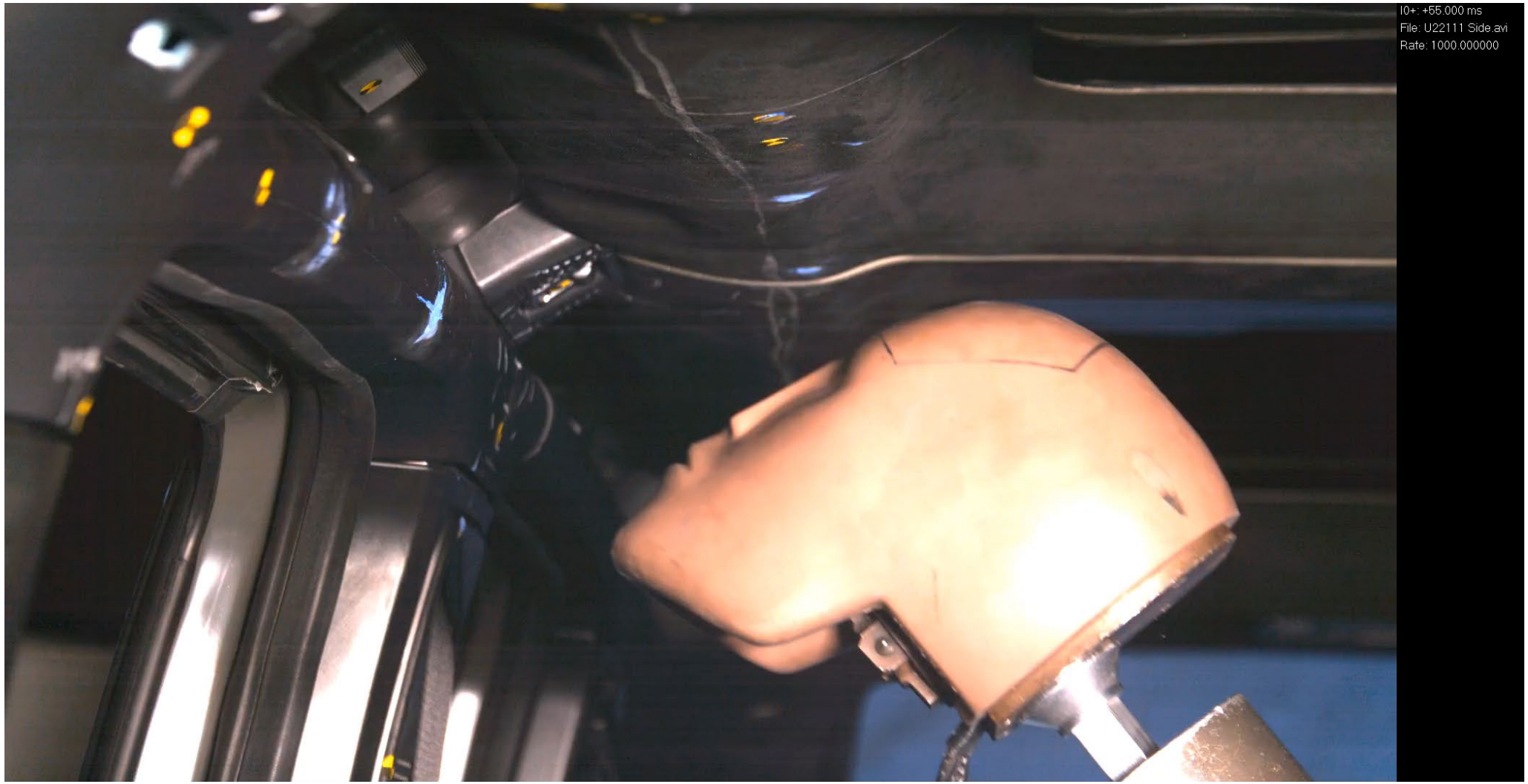
- Free Motion Head (FMH) is the impactor used for analyze, test and certificate vehicles to be sold on U.S. market for Interior Head Impact Upper (FMVSS201u).

- This impactor has the singularity to travel in the air for at least 20cm accordingly to TP201, this adds an ingredient of kinematic to the 201u impact event, unlike other impactors with rigid shafts-fixtures such as ejection mitigation, head impact lower or impactors with similar moments of inertia on each direction such as pedestrian protection.

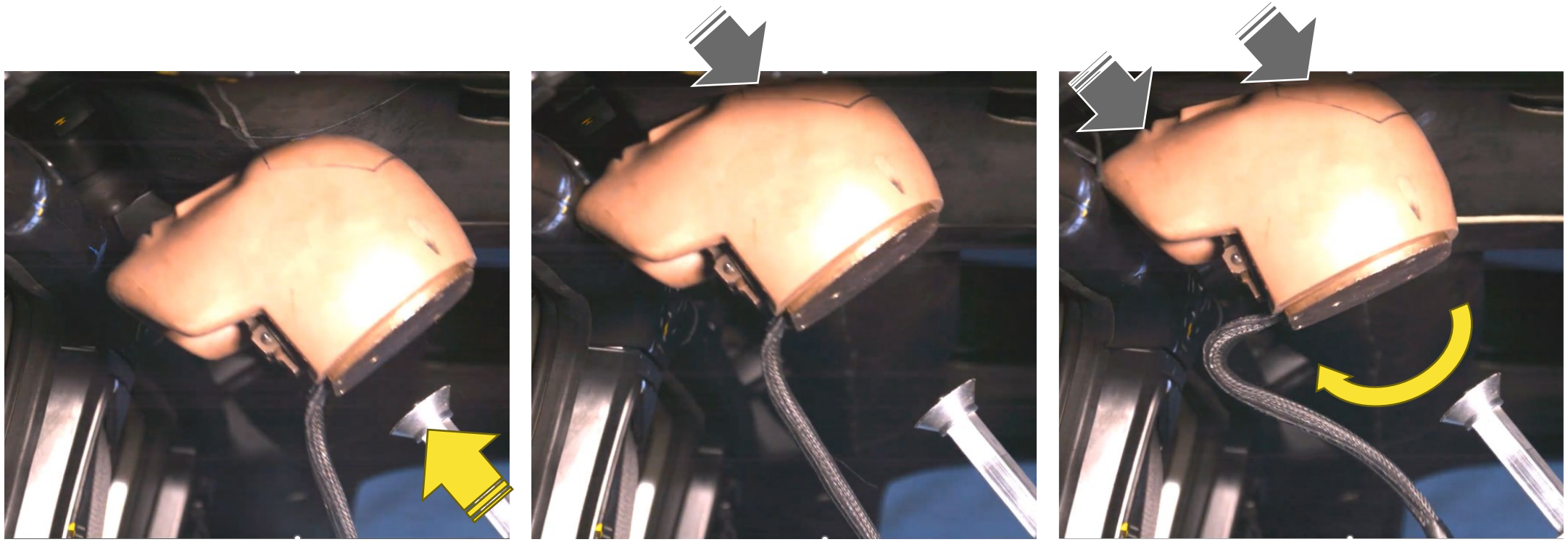
Challenge

- This impactor has the singularity to travel in the air for at least 20cm accordingly to TP201, this adds an ingredient of kinematic to the 201u impact event, unlike other impactors with rigid shafts-fixtures such as ejection mitigation, head impact lower or impactors with similar moments of inertia on each direction such as pedestrian protection.

Example of FMH kinematic, video:



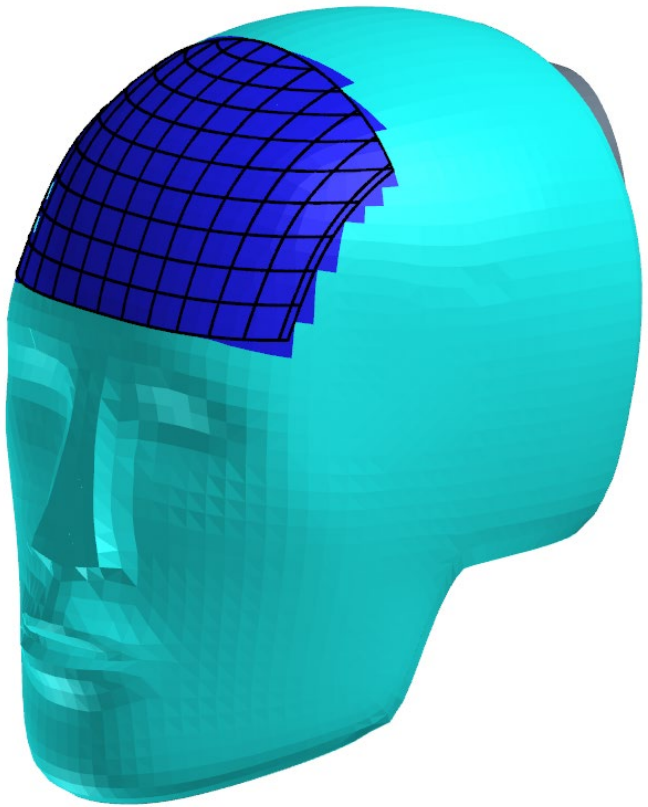
FMH, impact event:



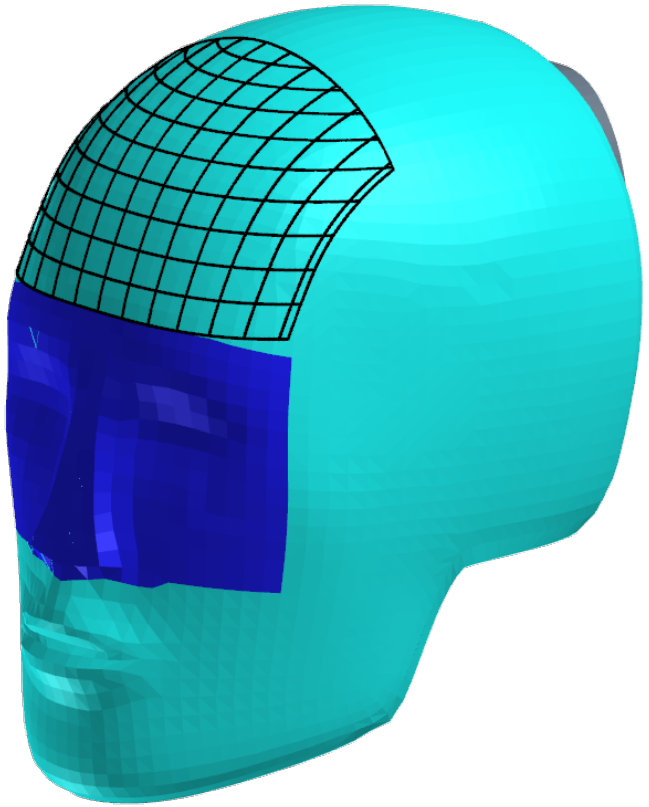
- FMH travels at least 20cm in rigid motion mode until touching Interior trim.
- Impactor has a first point of contact on fore head impact zone, the trim and BIW structure begins to absorb energy.
- Head form rotates over “ears axis” due to the room between the FMH chin and A-Surface (specified on TP201 due to back angle FMG setup).

Technique to understand interaction of FMH and interior trim

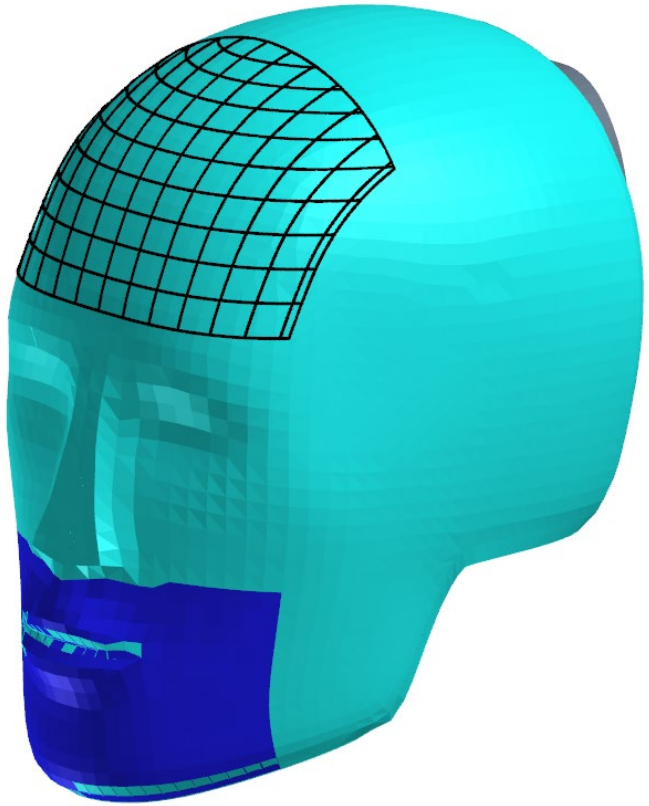
1010=>Contact Transducer Forehead



1020=>Contact Transducer Nose



1030=>Contact Transducer Mouth and Chin



Technique to understand interaction of FMH and interior trim

*CONTACT_FORCE_TRANSDUCER_PENALTY_ID

CID	NAME
1010	Contact Transducer Forehead

SSID	MSID	SSTYP	MSTYP	SBOXID	MBOXID	SPR	MPR
1072	0	1	0	0	0	0	0
FS	FD	DC	VC	VDC	PENCHK	BT	DT
0.	0.	0.	0.	0.	0	0.	1E20
SFS	SFM	SST	MST	SFST	SFMT	FSF	VSF
1.	1.	0.	0.	1.	1.	1.	1.

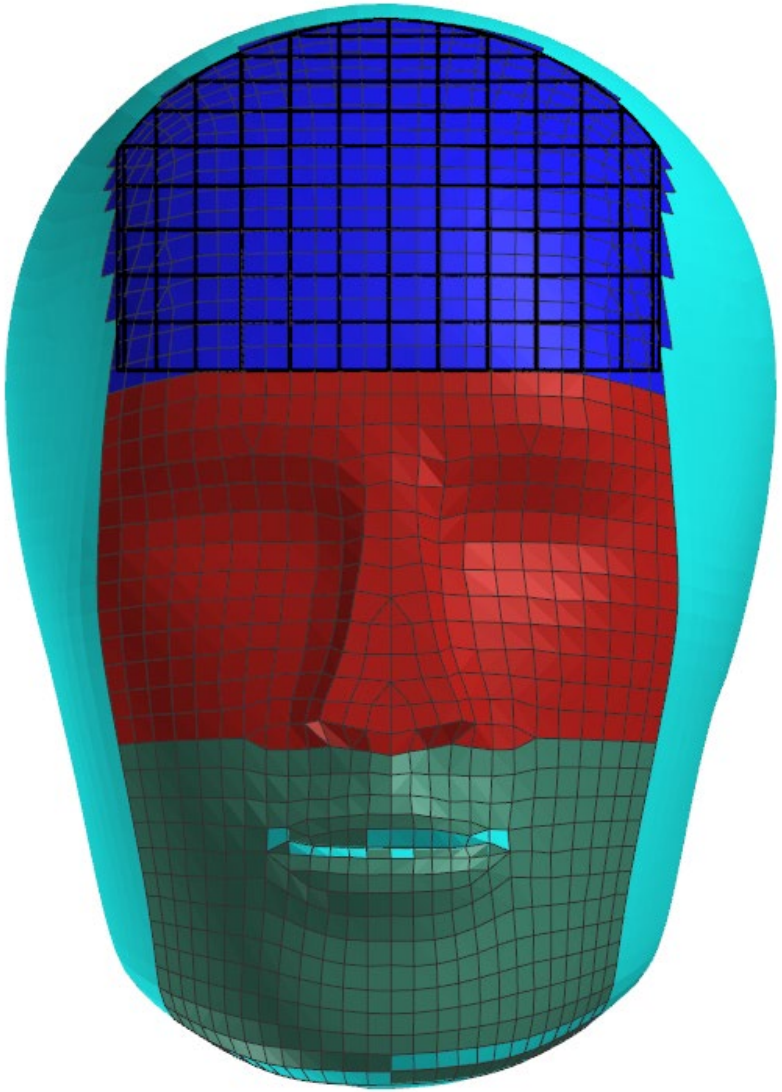
SOFT	SOFSCL	LCIDAB	MAXPAR	SBOPT	DEPTH	BSORT	FRCFRQ	)EPTH_F	ISORT_F
0	0.1	0	0.	0.	2.	0.	1.	0	0

PENMAX	THKOPT	SNLOG	ISYM	I2D3D	SLDTHK	SLDSTF
0.	0	0	0	0	0.	0.

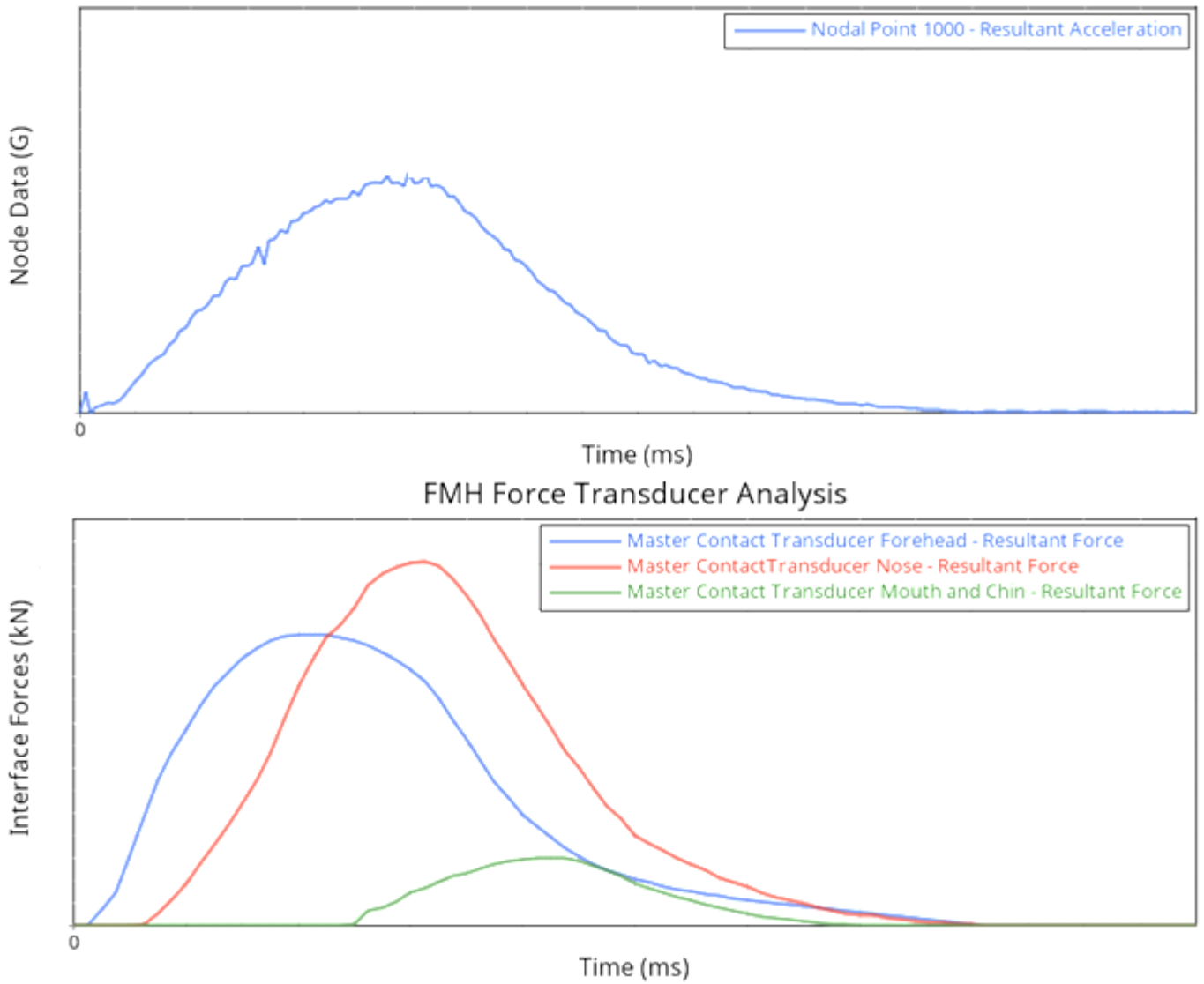
IGAP	IGNORE	DPRFAC	DTSTIF	FLANGL	CID_RCF	PRFAC_F	ITSTIF_F
0	0				0	0	0

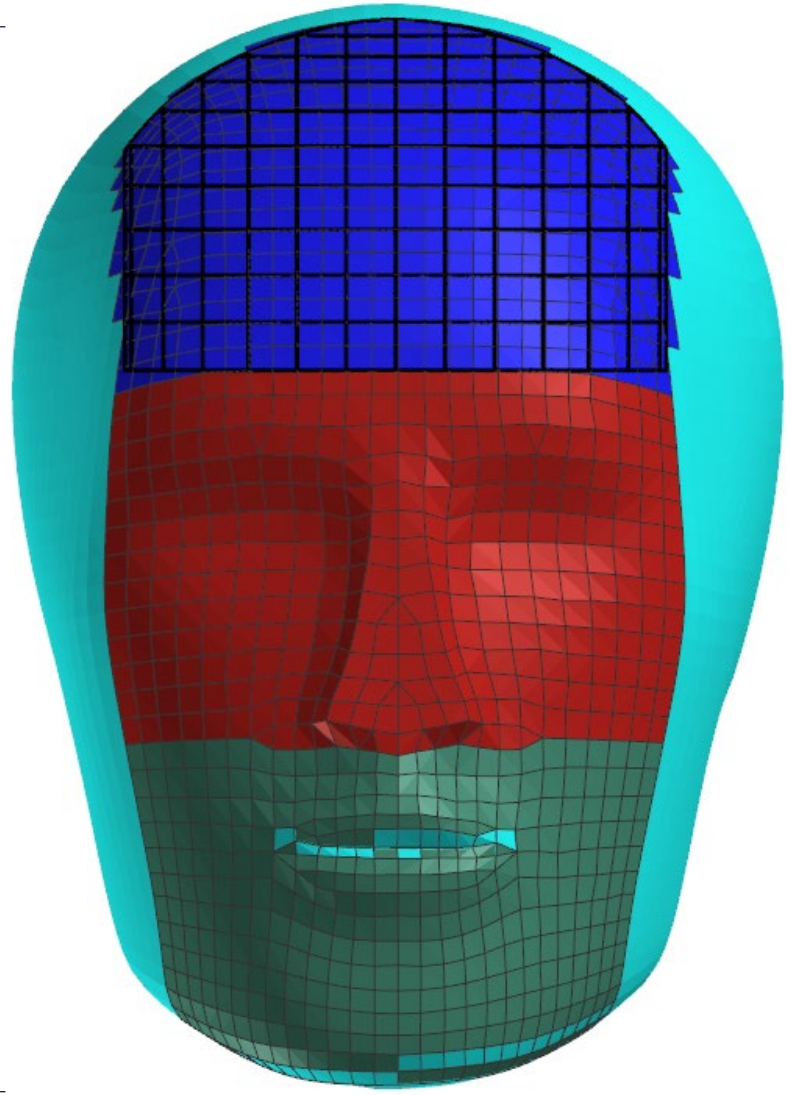
DTPCHK	SFNBR	FNLSCL	DNLSCL	TCSO	TIEDID	SHLEDG
					==	==

SHAREC	CPARM8	IPBACK	SRNDE
==	==		==

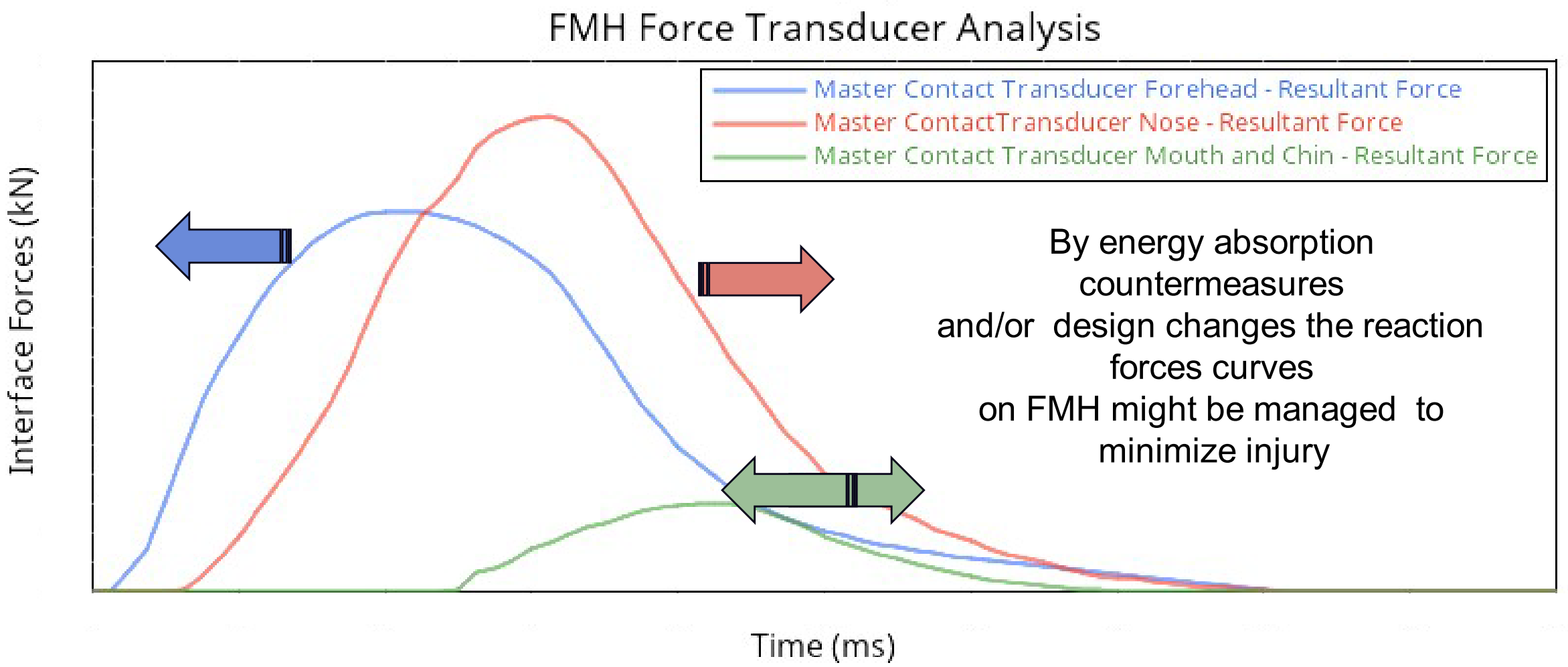


FMH Force Transducer example

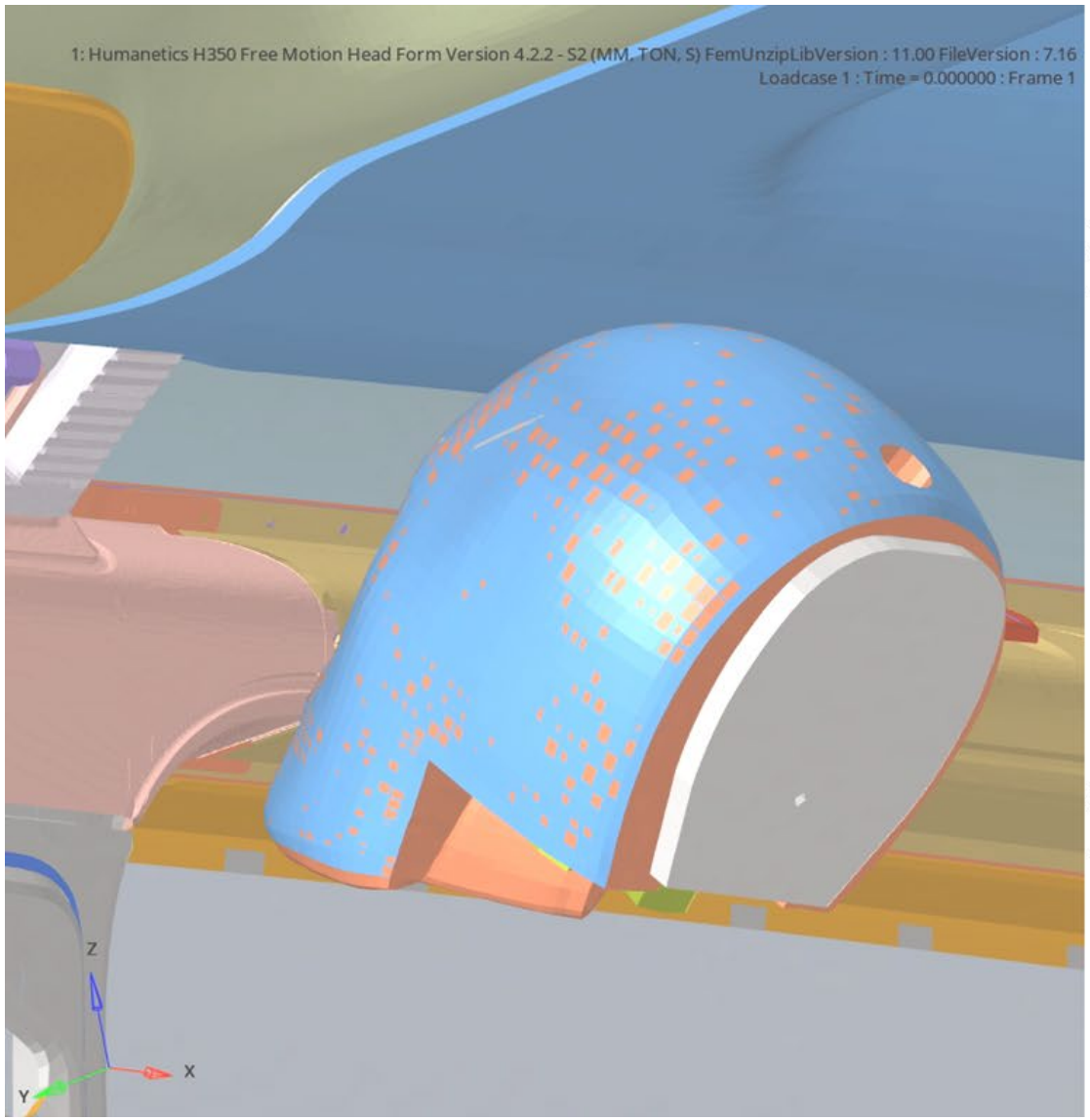


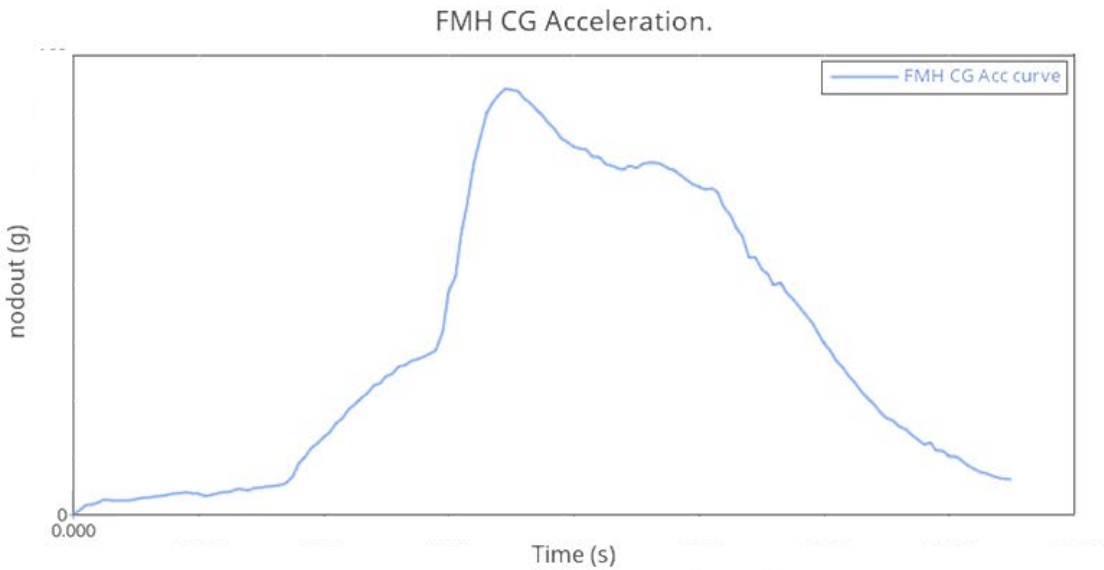


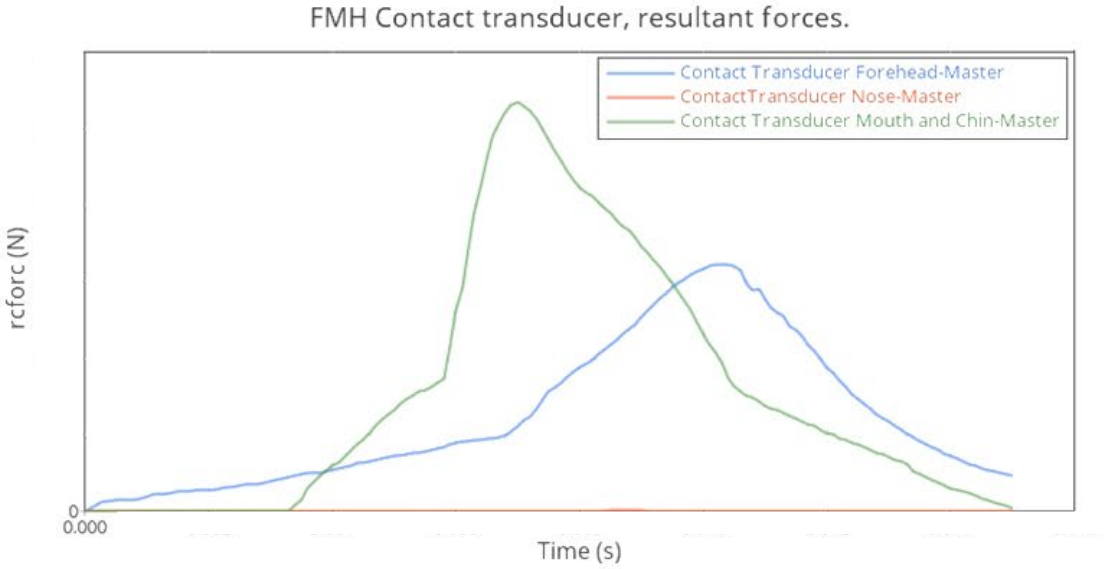
Technique to improve 201u performance



Example:

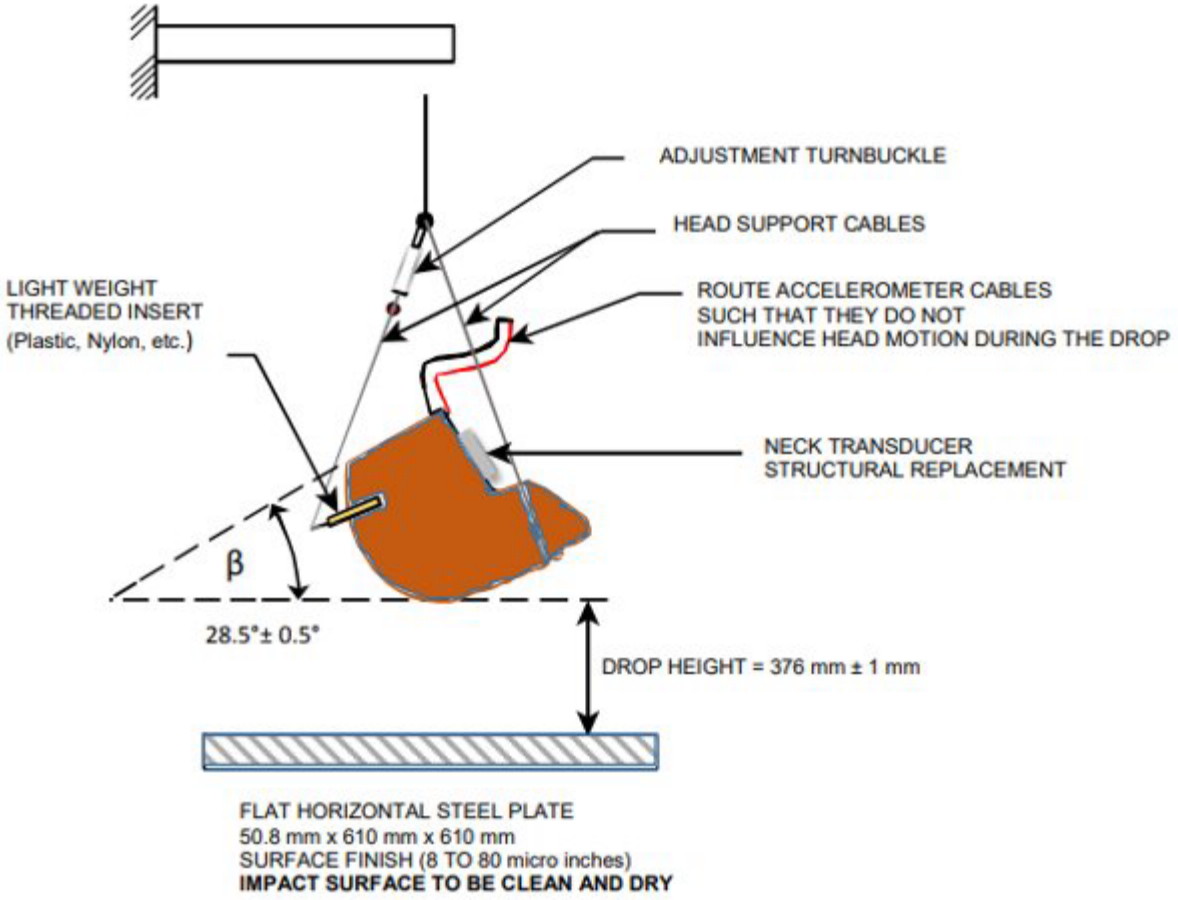

1: Humanetics H350 Free Motion Head Form Version 4.2.2 - S2 (MM, TON, S) FemUnzipLibVersion : 11.00 FileVersion : 7.16
Loadcase 1 : Time = 0.000000 : Frame 1
Z
X
Y


FMH CG Acceleration.
FMH CG Acc curve
nodout (g)
0
0.000
Time (s)


FMH Contact transducer, resultant forces.
Contact Transducer Forehead-Master
ContactTransducer Nose-Master
Contact Transducer Mouth and Chin-Master
rcforc (N)
0
0.000
Time (s)

Free Motion Head, calibration

NTHSA Calibration test, background.



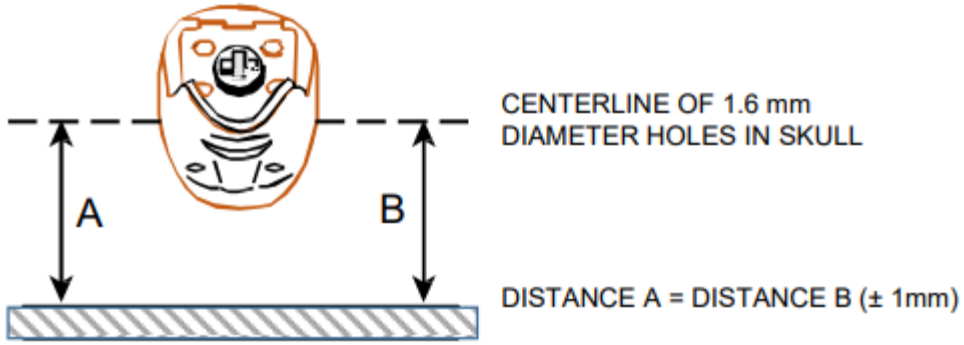
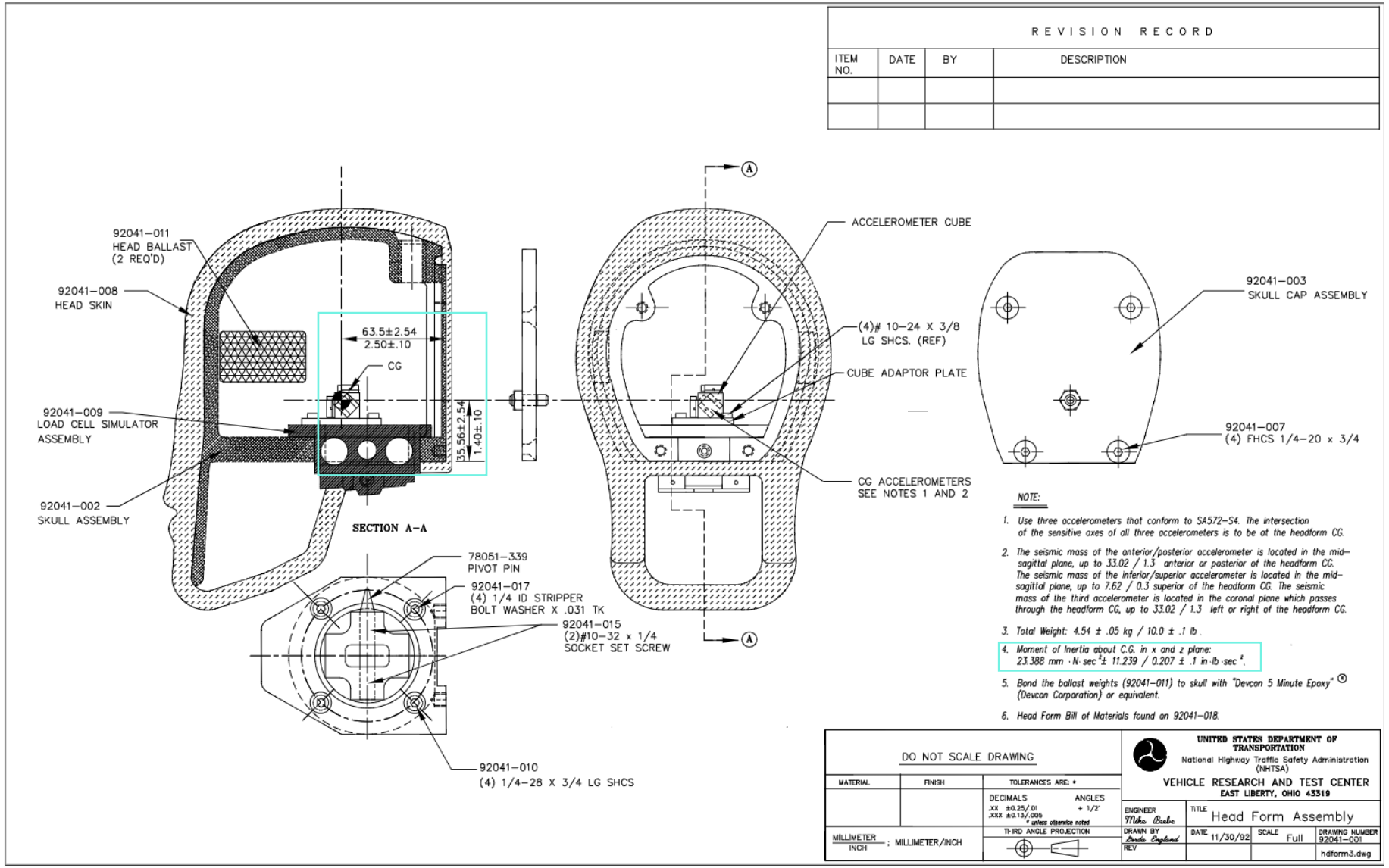


Table L1. Head Drop Test (S572.102)

Tested Parameter		Units	Specification	Result	Pass/ Fail
Head Assembly Soak Time		Minutes	240		
Temperature - During Soak	Max	°C	19 to 26		
	Min	°C			
Humidity - During Soak	Max	%	10.0 to 70.0		
	Min	%			
Temperature – During test		°C	19 to 26		
Humidity – During test		% RH	10.0 to 70.0		
FMH Mass		kg	4.54 ± 0.05		
Peak Head Resultant Acceleration		G	225 to 275		
Peak Lateral Acceleration		G	<15		
Uni-modal (Oscillation)?		Yes/No	<10%		

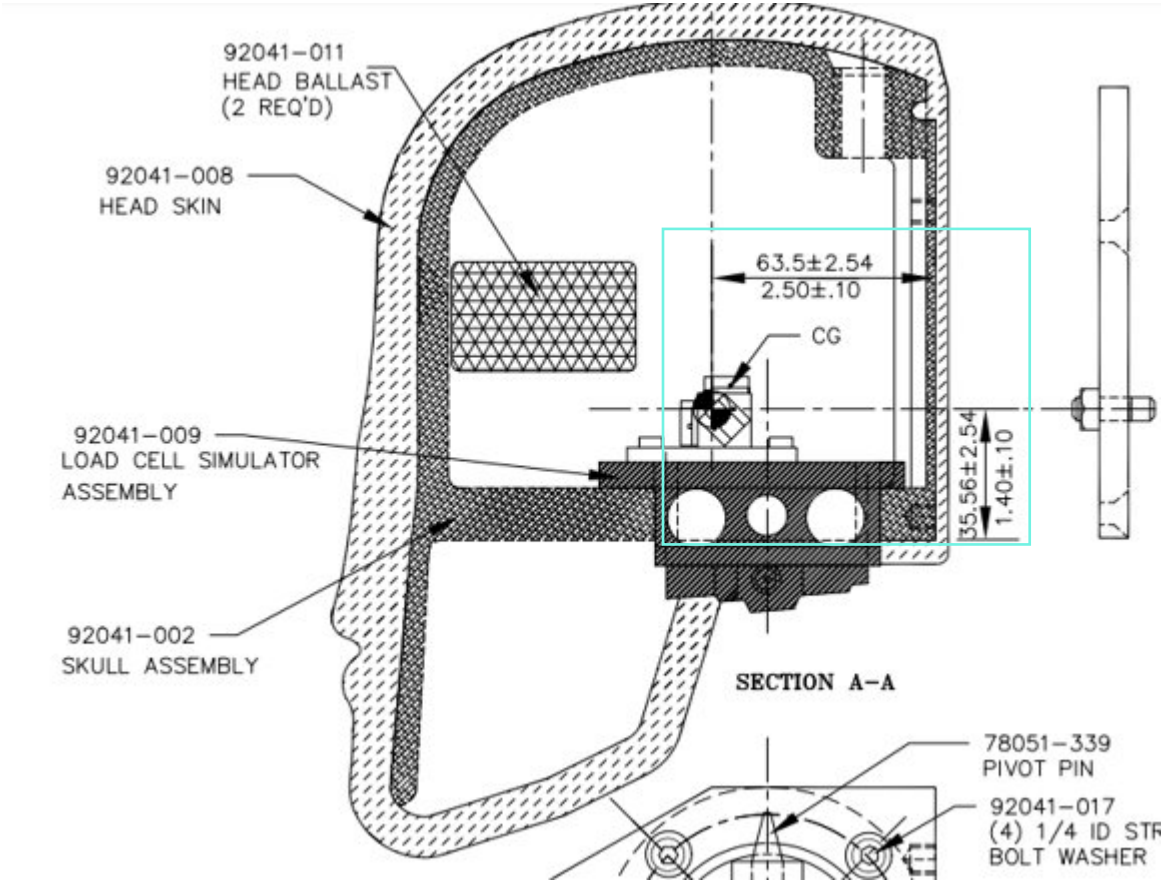
https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/tp-572-l-00.pdf
https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/tp-201u-01c_tag.pdf

NHTSA FMH Assembly Drawing:



https://static.nhtsa.gov/nhtsa/downloads/Test-Procedures/201U/tp-201u-02_appc_tag.pdf

NHTSA FMH Assembly, CG and inertial properties:



NOTE:

1. *Use three accelerometers that conform to SA572–S4. The intersection of the sensitive axes of all three accelerometers is to be at the headform CG.*
2. *The seismic mass of the anterior/posterior accelerometer is located in the mid–sagittal plane, up to 33.02 / 1.3 anterior or posterior of the headform CG. The seismic mass of the inferior/superior accelerometer is located in the mid–sagittal plane, up to 7.62 / 0.3 superior of the headform CG. The seismic mass of the third accelerometer is located in the coronal plane which passes through the headform CG, up to 33.02 / 1.3 left or right of the headform CG.*
3. *Total Weight: 4.54 ± .05 kg / 10.0 ± .1 lb .*
4. *Moment of Inertia about C.G. in x and z plane: 23.388 mm ·N· sec ^{2} ± 11.239 / 0.207 ± .1 in ·lb ·sec ^{2}.*
5. *Bond the ballast weights (92041–011) to skull with "Devcon 5 Minute Epoxy" ® (Devcon Corporation) or equivalent.*
6. *Head Form Bill of Materials found on 92041–018.*

LSTC Validated V2.0 FMH Model:

	2.72mm/ms. Drop test 376mm		Total mass (Kg)	Principal inertia (mm·KN·ms²)		
	Acceleration Peak (g)	Lateral Acceleration (g)		i11	i22	i33
NHTSA SPECIFICATION	225 TO 275	<15	4.5± 0.05	N/A	23,388± 11,239	N/A
LSTC V2.0 FMH Impactor	241	0.296 & -0.267	4.5393	1.95E+04	20,790.00	1.36E+04

Even though i22 is into NTHSA tolerance, there is still a slight area of opportunity

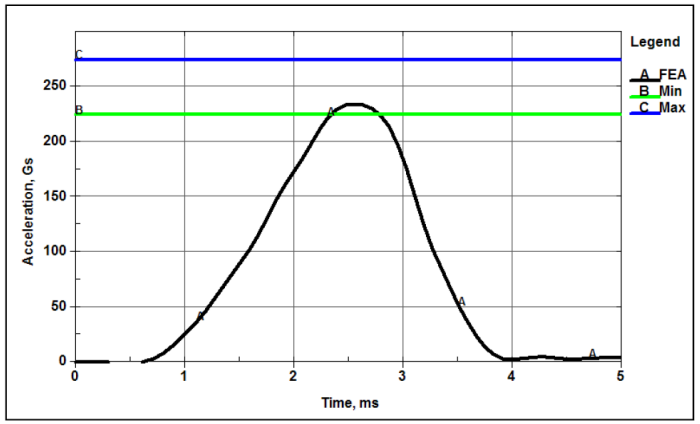


Figure 3 – 2.72m/s Calibration Test, Resultant Acceleration

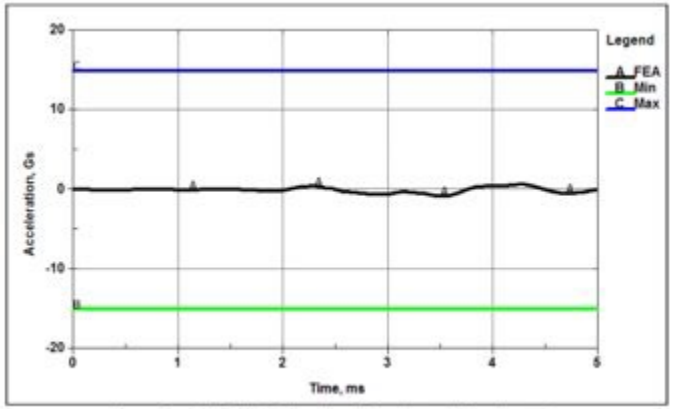


Figure 2 – 2.72m/s Calibration Test, Lateral Acceleration

Data and plots were copied from LSTC V2.0 manual

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FMH, slight improvements:

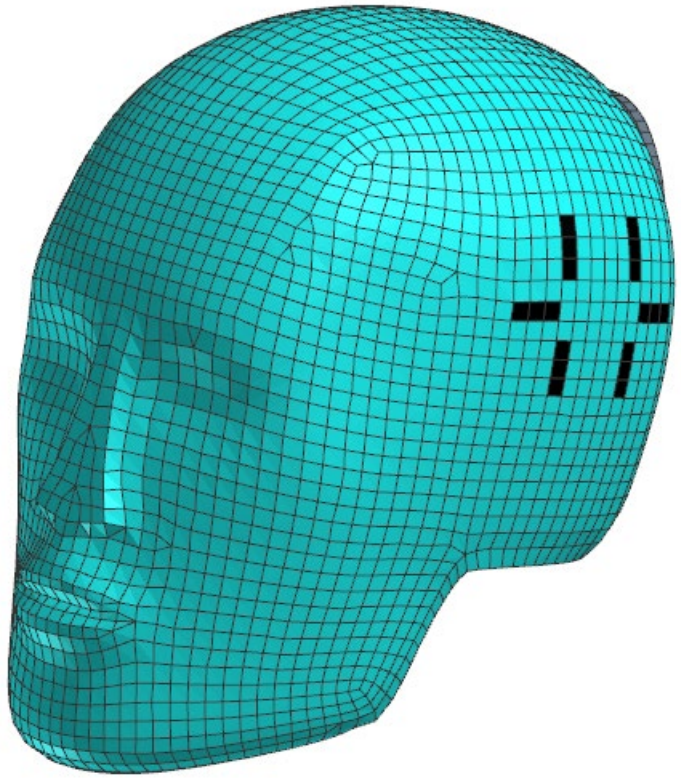
	2.72mm/ms. Drop test 376mm height		Total mass (Kg)	Principal inertia (mm·KN·ms²)		
	Acceleration Peak (g)	Lateral Acceleration (g)		i11	i22	i33
NHTSA SPECIFICATION	225 TO 275	<15	4.5± 0.05	N/A	23,388± 11,239	N/A
LSTC V2.0 FMH Impactor	241	0.296 & -0.267	4.5393	1.95E+04	20,790.00	1.36E+04
Slightly improved LSTC impactor	239	1.607 & -1.022	4.5385	1.95E+04	23,320.00	1.36E+04

	Reference Drop test at 4.0mm/ms. Acceleration Peak (g)	Reference Drop test at 6.71mm/ms. Acceleration Peak (g)
LSTC V2.0 FMH Impactor	446.17	1140.1
Slightly improved LSTC impactor	453.99	1143.55
Physical test results from LSTC FMH V2.0 Manual	437	1067

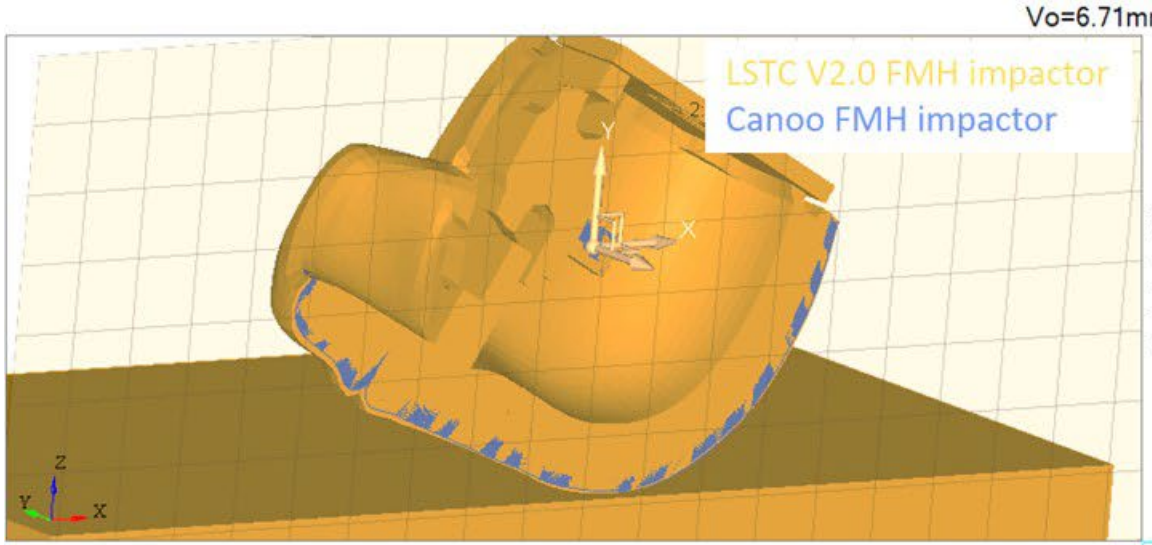
```
*****************************************************************

 m a s s   p r o p e r t i e s   o f   b o d y
    total mass of body          = 0.45276380E+01
    x-coordinate of mass center = 0.74414454E-01
    y-coordinate of mass center = 0.75828226E-03
    z-coordinate of mass center =-0.47634420E+01

    inertia tensor of body
    row1=     0.1679E+05     0.2857E-01    -0.2983E+04
    row2=     0.2857E-01     0.2332E+05     0.1957E-01
    row3=    -0.2983E+04     0.1957E-01     0.1619E+05

    principal inertias of body
    i11 =     0.1949E+05
    i22 =     0.2332E+05
    i33 =     0.1349E+05

    principal directions
    row1=     0.7415E+00     0.3856E-05     0.6709E+00
    row2=    -0.2101E-05     0.1000E+01    -0.3426E-05
    row3=    -0.6709E+00     0.1131E-05     0.7415E+00

*****************************************************************
```

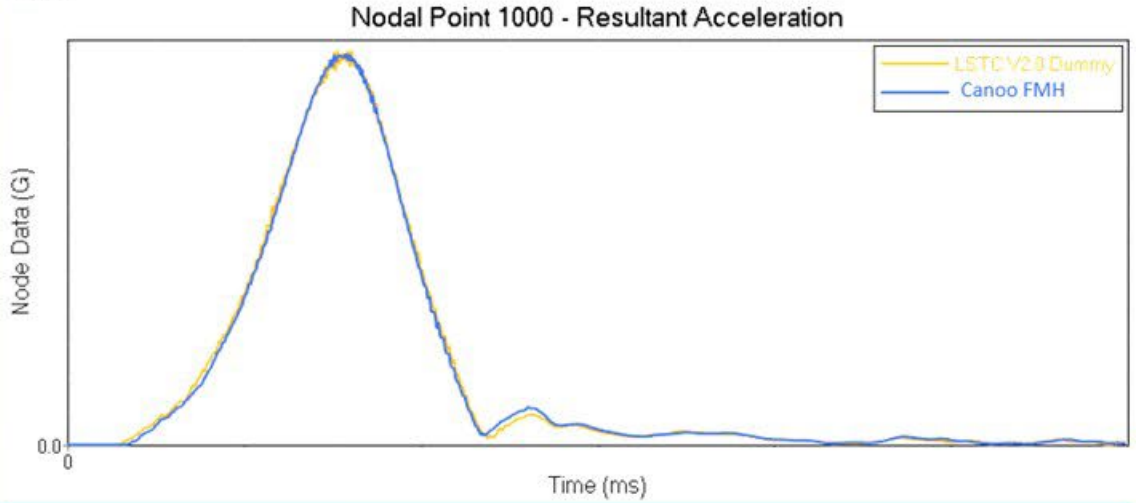
CGz, moved -0.47mm

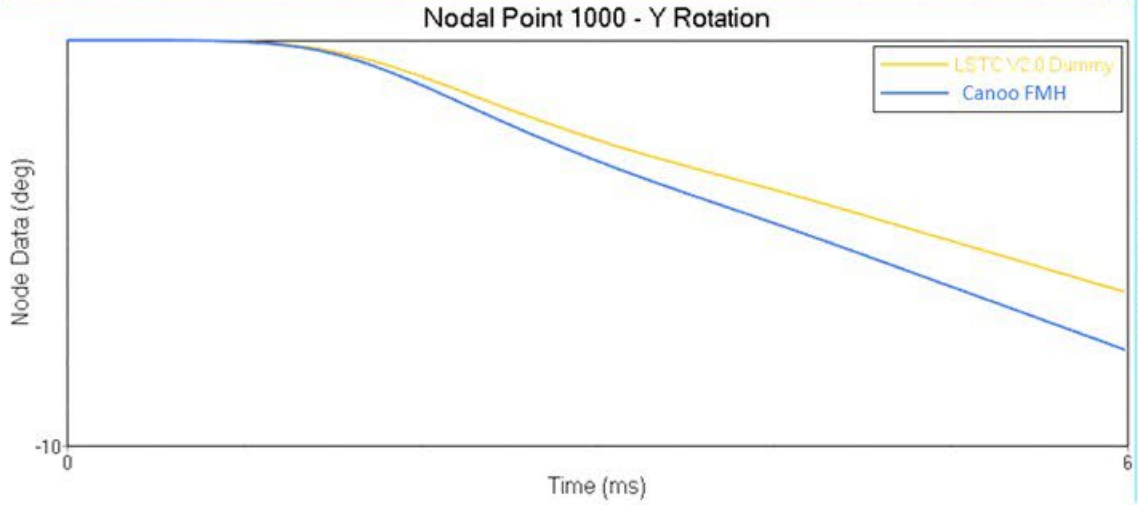
Modified Iyy moment

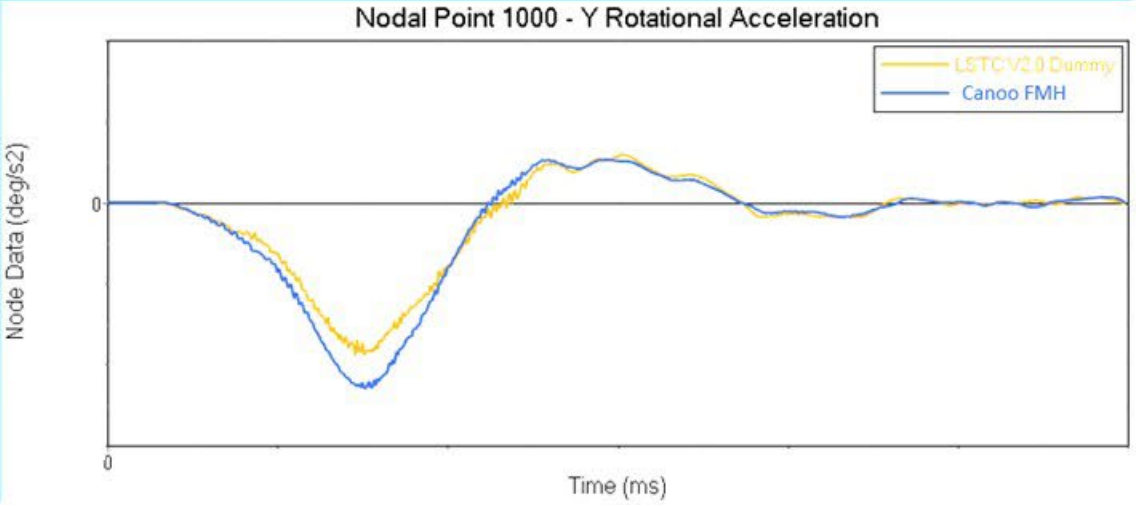


Rotational comparison









Conclusion

- As presented, during Free Motion Head impact event, there are kinematic considerations to better understanding the behaviour and interpretation of the FMH CG Acceleration curve, the methodology consist of extract more information than acceleration curve from FMH simulation, with addition of contact transducers can be obtained the forces due to the FMH and interior trim interaction, separating the FMH face by areas.

- Also is shown the importance of the extra calibration of the Free Motion Head impactor close to NTHSA nominal values of moments of inertia and center of gravity location, this approximation can yield more accurate CAE predictions to physical testing.

THANK YOU

Discussion: Q & A