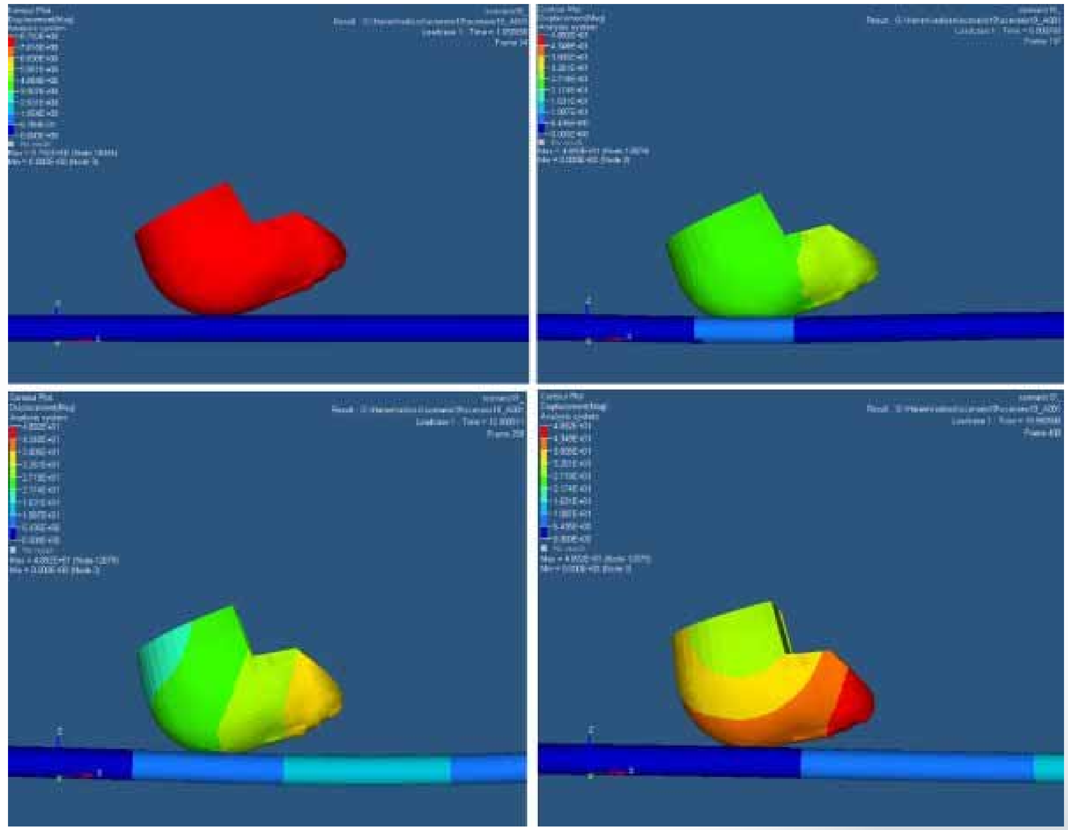
Head impacts against grabpole in railway transports



EHTC – Ludwigsburg, November 4th, 2009

Gaëtan HANEN (*gaetan.hanen@inrets.fr)*
Marie-Christine CHEVALIER
Thomas ROBERT
INRETS - LBMC

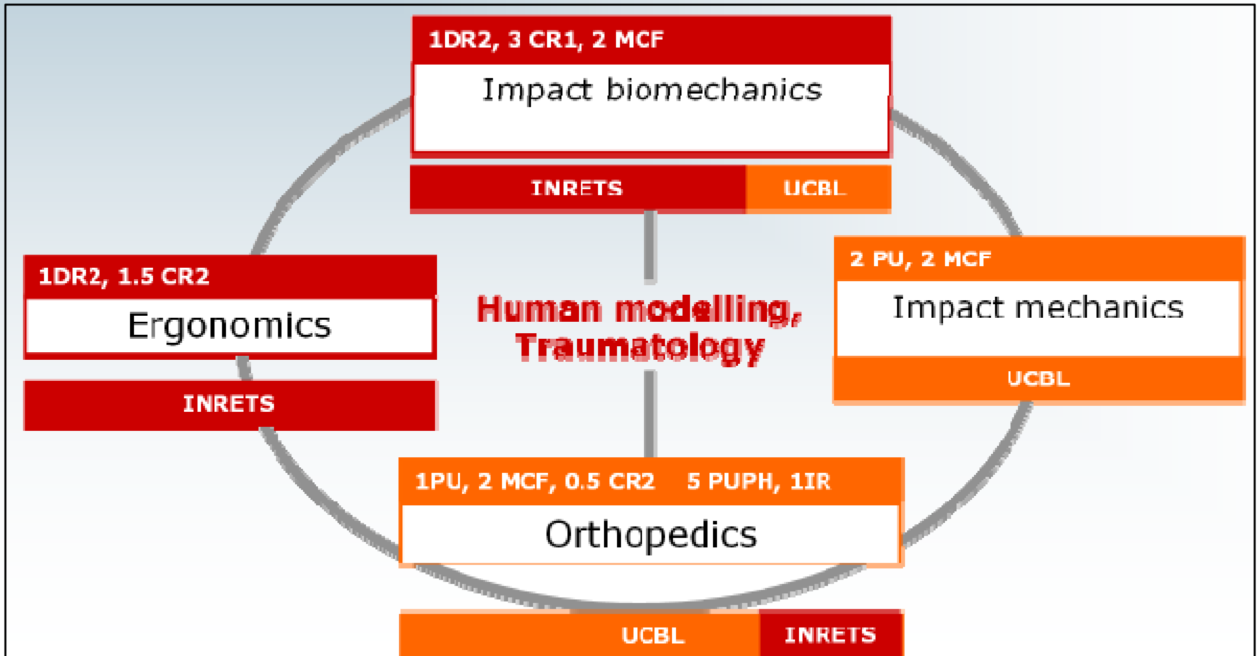
SAFE INTERIORS

INRETS
Institut national de recherche sur les transports et leur sécurité

INTRODUCTION: *LBMC*

INRETS
Institut national de recherche sur les transports et leur sécurité

Université Claude Bernard Lyon 1



LBMC (Biomechanics and Impact Mechanics Laboratory) – ***Dir: Philippe VEZIN***

INRETS
Institut national de recherche sur les transports et leur sécurité
SAFE INTERIORS

CONTEXT: grabpoles in railway transports

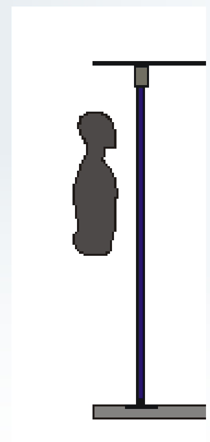
European Project devoted to interior design of railway vehicles
3.5 Years - ends June 2010
Other partners: *Siemens, Alstom, DB, RSSB, BT, CIDAUT, IST, MIRA, VUKV…*
Website: www.eurailsafe.net

GRABPOLES

- Common furniture in railway vehicles
- Security or structural purposes
- Located in « standing areas »

STANDING PASSENGERS IN CRASH

- Ejected in case of crash
- Impact with environment is likely to occur
- No time to react / avoid obstacles



What is the likeliness of injury when impacting a grabpole ?

CONTEXT: general scenario

What is the likeliness of head injury when impacting a grabpole ?

***SafeInteriors*' background**
Volunteers tests
Initial full-body simulations
Posture studies

INJURY EVALUATION

NUMERICAL TESTING | **PHYSICAL TESTING**

TEST MATRIX
Various parameters: velocity, impact point…

TOOLS
Numerical models (FEM)
Material Characterization

TOOLS
Headform impactor (FMH)
Grabpole
Test rig

RECOMMAND A TEST PROCEDURE
for the evaluation of grabpole

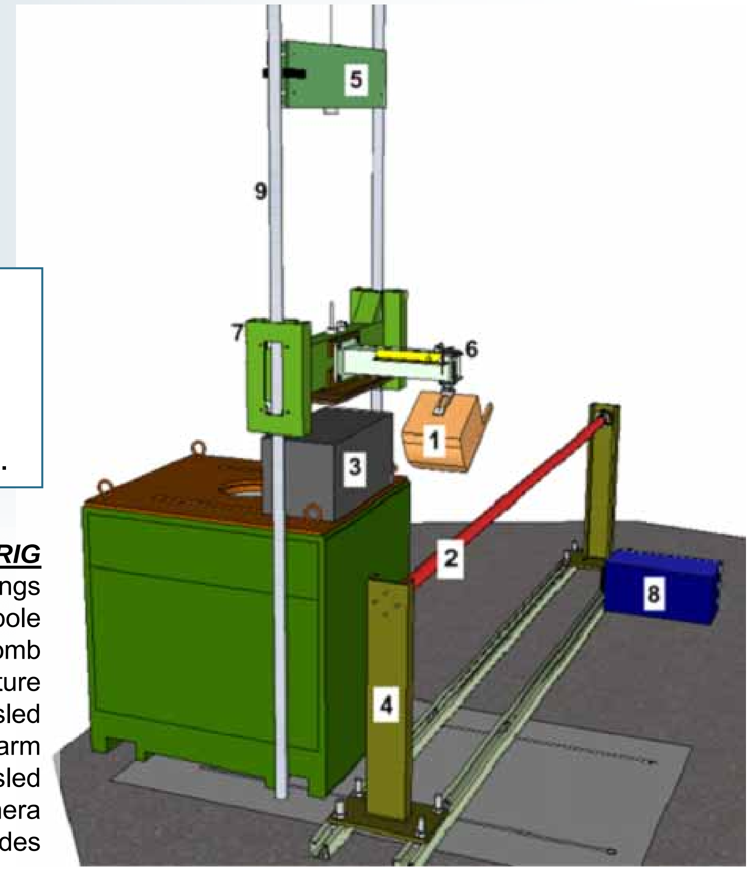
PHYSICAL TESTING

EVALUATION TOOL: FMVSS201 HEADFORM

Hybrid III headform without nose
Assessing interiors in automotive industry
Head is the most exposed part of the body

PROCESSUS OF A TEST

a – Release of the system. Headform is guided by sled.
b – Headform is separated from sled.
c – Sled is stopped by honeycomb . Headform continues to fall.
d – Headform impacts the grabpole in the targeted configuration.



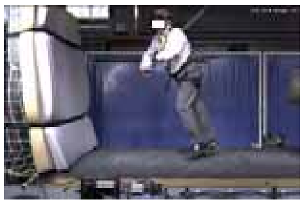
VERTICAL TEST RIG

1 – Headform with its fixings
2 – Grabpole
3 – Honeycomb
4 – Grabpole structure
5 – motorized sled
6 – Release arm
7 – Free Fall sled
8 – High-speed camera
9 – Test rig guides

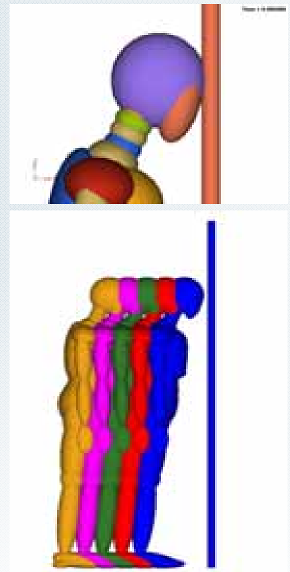
TESTING PARAMETERS

DETERMINATION OF INITIAL CONDITIONS FOR THE TESTS

***SafeInteriors* background**
Volunteers tests
Posture studies



SafeInteriors grabpole scenario
Crash pulse: 5g, 100ms
Distance to grabpole 25-50cm

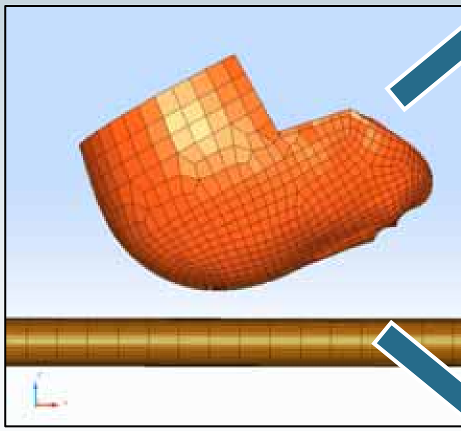


Full body simulations using **MADYMO**
(performed at CIDAUT)

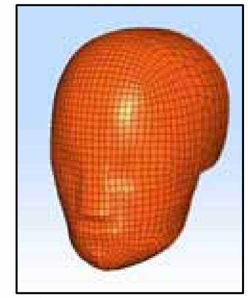
Head Impact Reference parameters

Velocity at impact: 5.23m/s
Head angle: 24.5°
Impact point on grabpole: 1.75m
Correlation full body/head assessed

FINITE ELEMENT MODELS

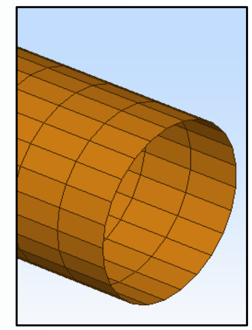


ALTAIR FREE MOTION HEADFORM
– Aluminum skull (Rigid Body)
– Hyperelastic foam skin (Law 42)
– 4716 elements (3D)
– Matching FMVSS201 requirements
– Initial velocity



General interface (7) between both parts

GRABPOLE FEM
– Shell elements (2D)
– Size: 2200 x 35mm (wall thickness: 2mm)
– Stainless steel 304 through Johnson-Cook Law



FINITE ELEMENT MODELS

REFERENCE SCENARIO →

INFLUENCE OF PARAMETERS (ALONE OR BY PAIR)

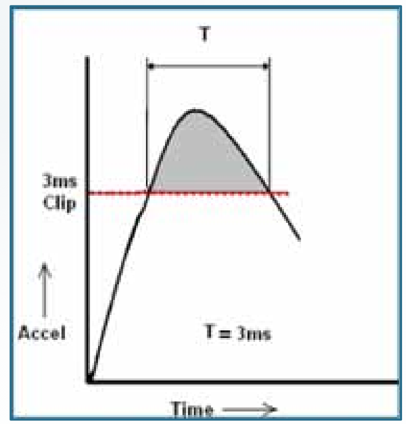
VELOCITY	***HEAD ANGLE***
OFFSET	***IMPACT POINT***

↓

INJURY CRITERIA

$$\left[\frac{1}{t_2 - t_1}\int_{t_1}^{t_2} a\,dt\right]^{2.5}(t_2 - t_1)$$

HIC_{15}

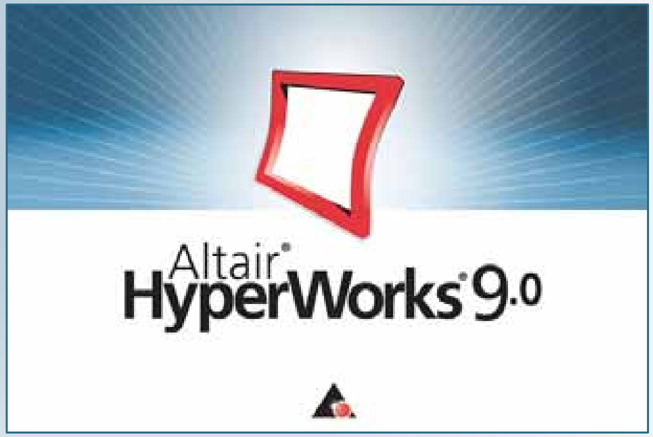


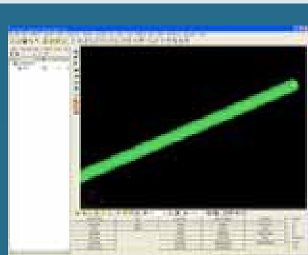
3ms clip

Moderate risk	*Serious* risk	*Serious* risk
HIC = 150	**HIC = 500**	**3ms clip = 80g**

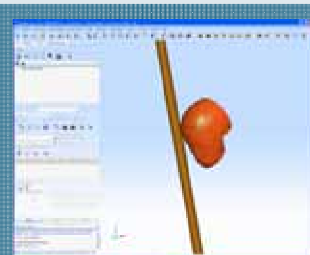
G Hanen, M-C Chevalier, T Robert, INRETS-LBMC

FINITE ELEMENT MODELS



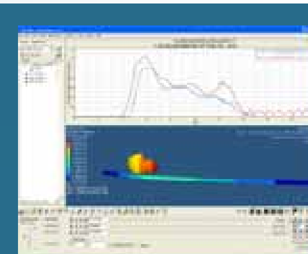


Meshing Model:
HyperMesh



Settings:
HyperCrash

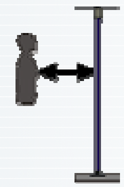
RADIOSS



Analysis
HyperGraph
HyperView

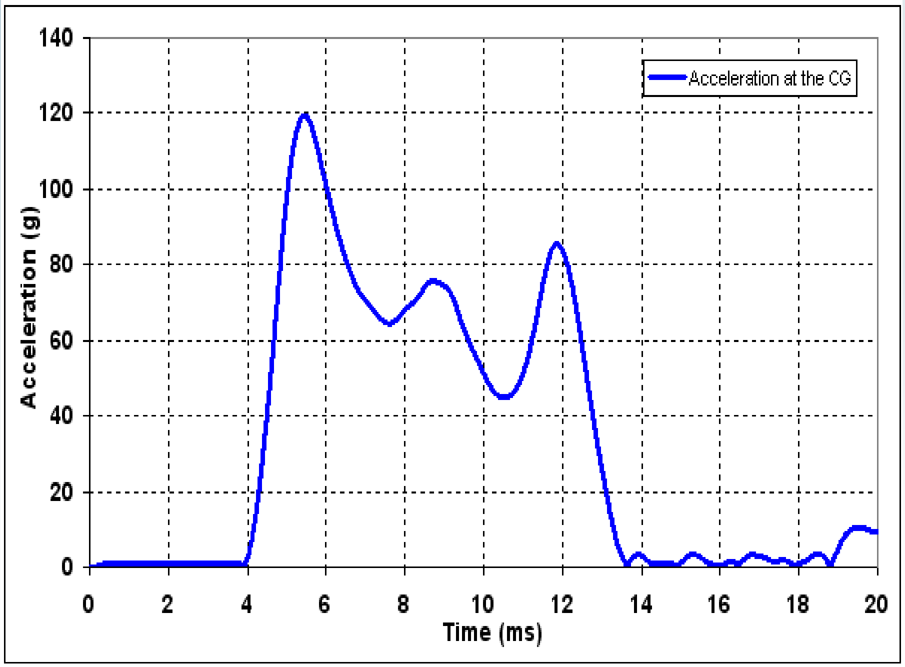
RESULTS – Reference scenario

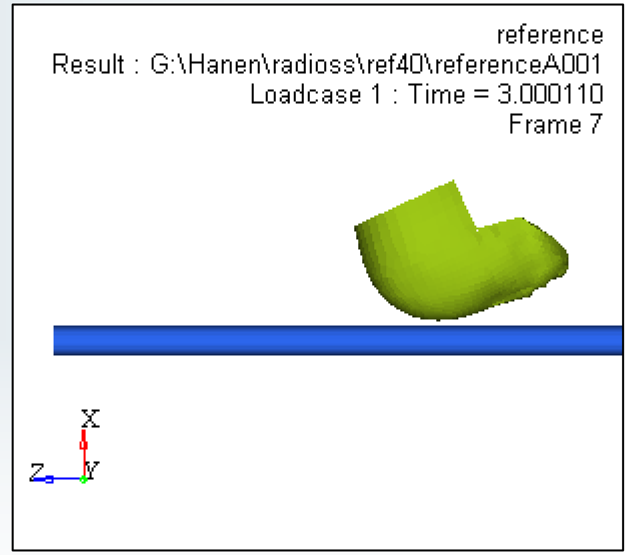
- Impact point on grabpole: 1750mm
- Head angle: 24.5°
- Velocity: 5.23m/s
- Central line of the head



Real-life equivalent scenario

Standing in front of a grabpole
Distance: 25cm
Crash: 5g pulse, 100ms



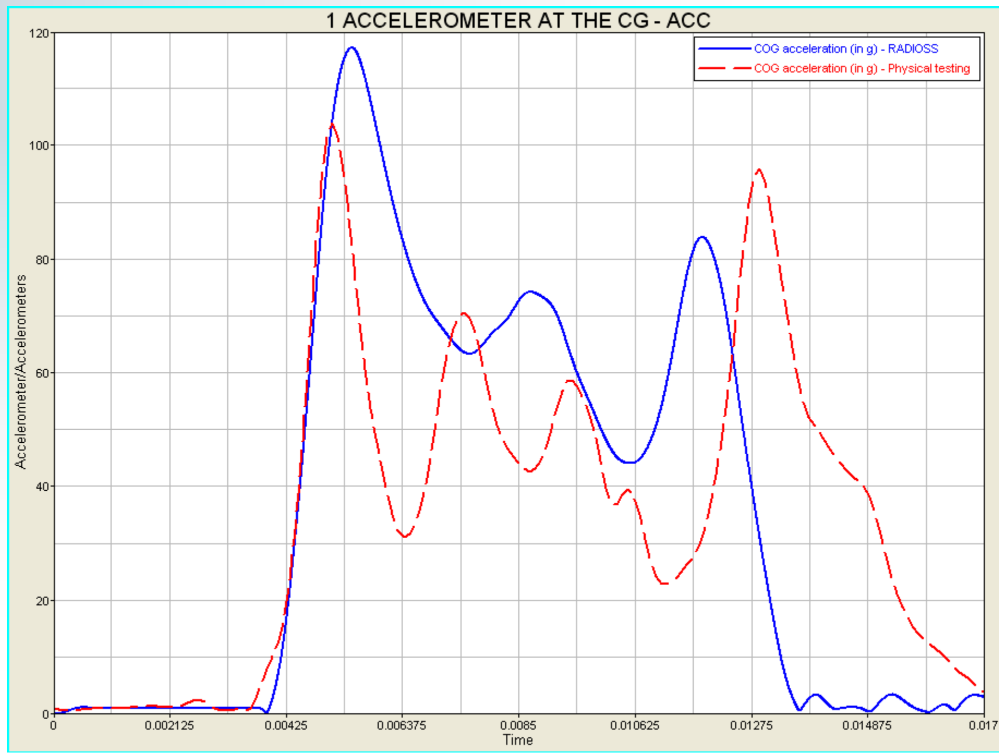


HIC_{15} = 355
3ms-clip = 63g
a_{max}= 120g

RESULTS – Reference scenario (physical pre-test)

Validation of the numerical results (currently under way)

– Same general behavior
– Double peak observed
– Lower results and length of impact due to the limited rigidity of the rig (modifications underway)



Reference scenario physical (pre-test) and numerical results

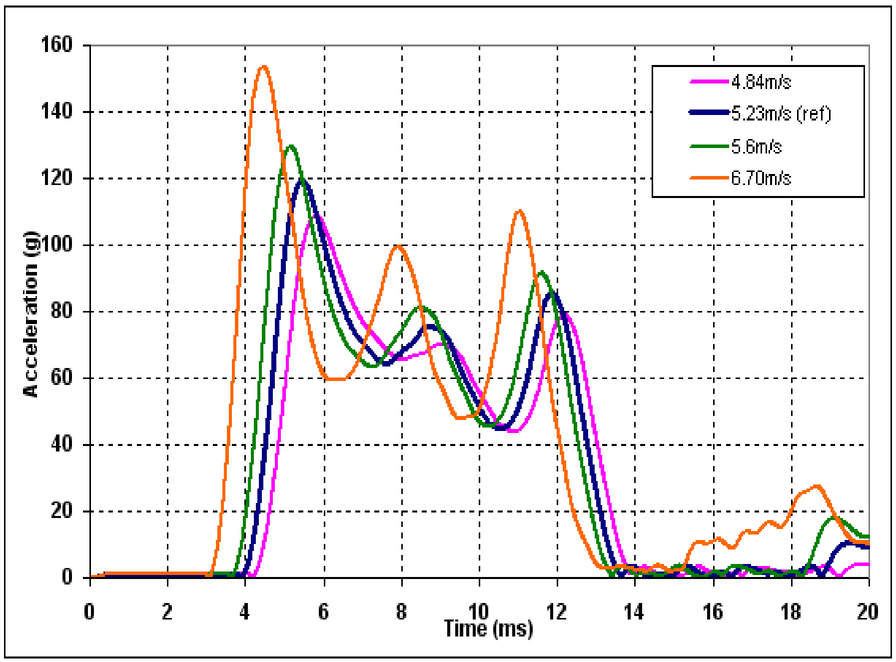
RESULTS: alternative impact speeds (numerical)

Mean observed distance to grabpoles (SafeInteriors project)
25 to 50cm

Crash pulse

→

Velocity range of interest
4.84m/s
5.23m/s
5.60m/s
6.70m/s



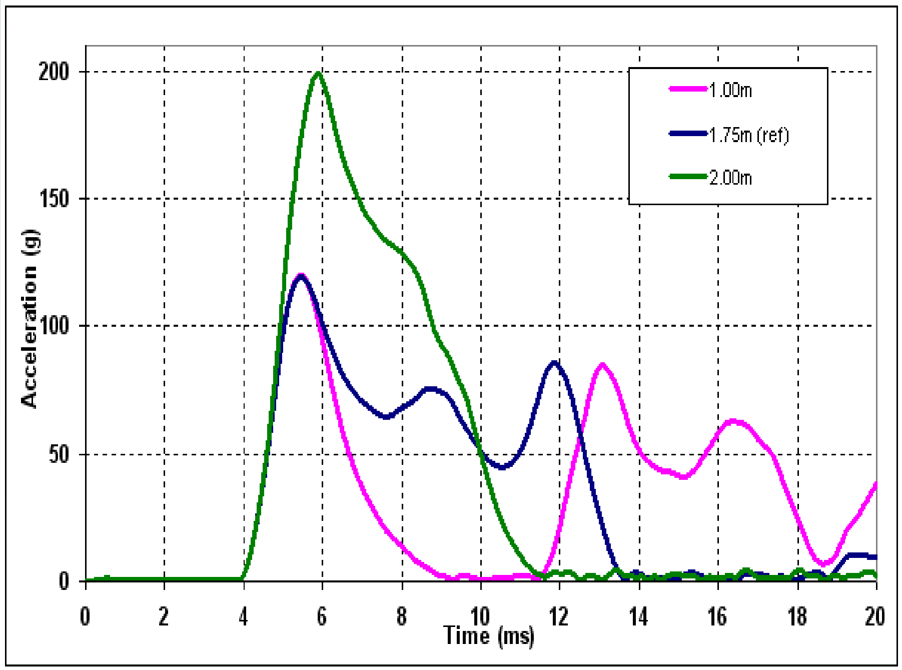
6.70m/s (HIC_{15}=509, a_{max}=151g)
5.60m/s (HIC_{15}=394, a_{max}=128g)
5.23m/s (HIC_{15}=355, a_{max}=118g) – ref.
4.84m/s (HIC_{15}=314, a_{max}=106g)

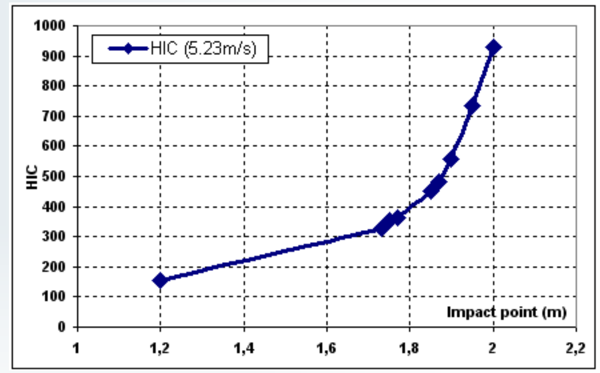
HIC increases with impact velocity

RESULTS: alternative impact points on grabpole

<u>IMPACT POINT ON THE GRABPOLE</u>

– Idea: compare extrems situations to reference
– Three heights considered : 1.0m, 1.75m, 2.0m



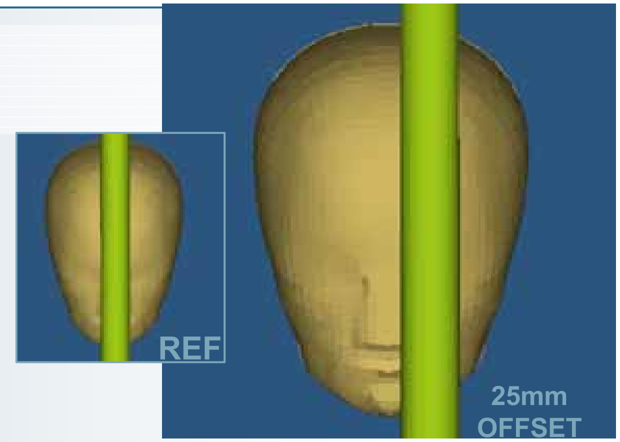


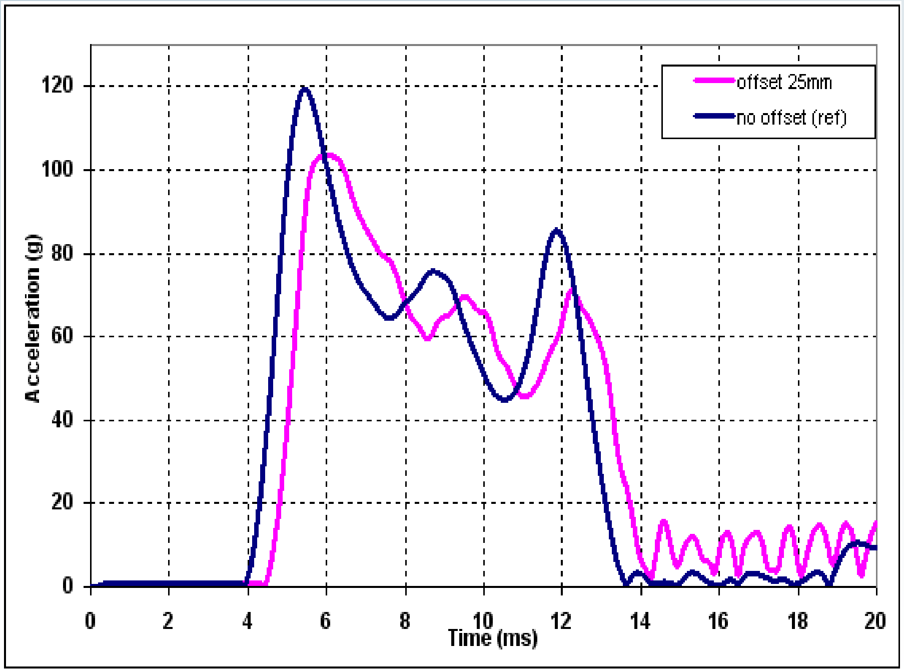
2.00m (HIC_{15}=1017, a_{max}=195g, 3ms clip=123g)
1.75m (HIC_{15}= 355, a_{max}=118g, 3ms clip=63g) - ref
1.00m (HIC_{15}= 156, a_{max}=101g, 3ms clip=40g)

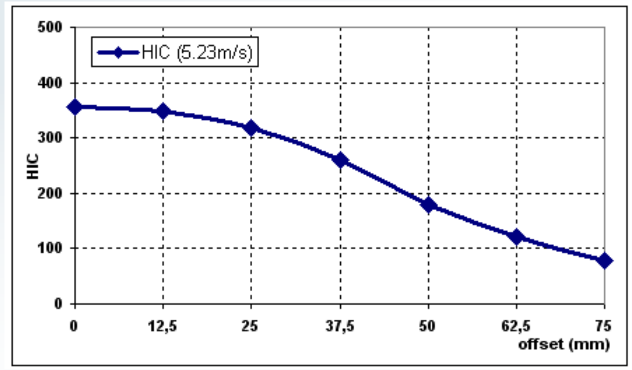
– Injury risks increase with impact height on grabpole
– Correlation between grabpole deformation & distance to fixings
– Double impact clearly observed for impacts on midpoint

RESULTS: alternative impact line

- Impact out of centre line of the head
- Presence of offset is the most common case







Centre line (HIC_{15}=355, a_{max}=118g) – ref.

Excentred (HIC_{15}=319, a_{max}=102g)

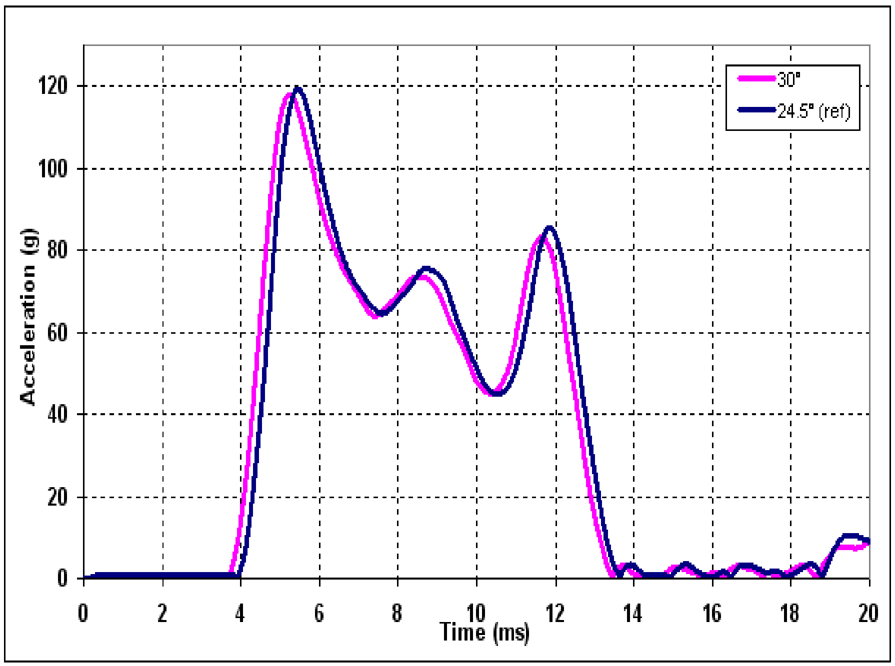
Most common case is the safest

RESULTS: alternative head angle

FMH Certified impact area
Regulation angle 28.5°

Exploration of sensitivity of result

Head angle
24.5° (reference)
30.0° (alternative)



30.0° (HIC_{15}=352, a_{max}=115g)
24.5° (HIC_{15}=355, a_{max}=118g) – ref.

The angle plays no significant role in injury mechanism

RESULTS: summary

num	velocity (m/s)	Impact point (m)	Offset (mm)	Head Angle (°)	HIC_{15}	3ms-Clip (g)	A_{max} (g)
ref	**5,23**	**1,75**	**0,0**	**24,5**	**355**	**63**	**120**
2	4,84	1,75	0,0	24,5	314	64	108
3	5,60	1,75	0,0	24,5	394	62	127
4	6,70	1,75	0,0	24,5	509	58	151
5	5,23	1,75	0,0	30	352	63	115
6	5,23	1,75	25,0	24,5	319	63	103
7	5,23	2,00	0,0	24,5	1017	123	195
8	5,23	1,00	0,0	24,5	156	40	117
9	4,84	2,00	0,0	24,5	930	120	185
10	4,84	1,75	25,0	24,5	280	66	94
11	4,84	1,75	0,0	30	311	61	105
12	5,23	1,75	25,0	30	322	63	104
13	5,23	2,00	25,0	24,5	963	120	186
14	5,23	2,00	0,0	30	1018	125	195
15	5,60	2,00	0,0	24,5	1106	128	204
16	5,60	1,75	25,0	24,5	357	61	111
17	5,60	1,75	0,0	30	391	61	126
18	6,70	2,00	0,0	24,5	1423	142	225
19	6,70	1,75	25,0	24,5	470	54	147
20	6,70	1,75	0,0	30	506	58	150
21	5,23	1,00	25,0	24,5	142	43	110
22	5,23	1,00	0,0	30	154	40	116
23	4,84	1,00	0,0	24,5	131	38	107
24	5,60	1,00	0,0	24,5	185	41	128
25	6,70	1,00	0,0	24,5	281	46	153

Matrix of simulation with results

Yellow indicates a parameter differing from the reference scenario

HIC

INFLUENCE

→ Velocity range
→ Impact point (close/far from midpoint)
→ Offset

NO INFLUENCE

→ Headform angle

3ms-clip

INFLUENCE

→ Impact point (close/far from midpoint)

NO INFLUENCE

→ Headform angle
→ Velocity
→ Limited offset

DISCUSSION

Outputs of the study

– Ability to describe influence of each parameter on the injury risk
– Worst cases identified
– Numerical results in accordance with the first physical tests

Limitations

– One single kind of grabpole was tested.
– Only « facing travel direction » scenario at this point

INJURY LEVEL LIMITS

SafeInteriors recommandations for rail vehicles

Moderate risk (20% risk of AIS2+)	*Serious* risk (20% risk of AIS3+)
HIC = 150	**HIC = 500**

3 ms acceleration peak: **3ms clip = 80g**

INJURY LEVEL

Reference scenario

HIC = 355

3ms clip = 63g

Possible improvement
Second phase of testing

CONCLUSION

Injury likeliness on grabpoles

•Head is the most exposed part of the body in case of impact against grabpole

•Some impact parameters are more likely than others to cause severe injuries

•Injury risk is acceptable but has still to be reduced by working on design/materials

SAFEINTERIORS TESTINGS	
STANDING PASSENGERS *(Grabpoles evaluation)* INRETS scenario	**SEATED PASSENGERS** *(in line, face to face, low backseat…)* Experimentation led by other partners

Improvement of safety for railway vehicles' interiors by:

Better understanding of the injury mechanisms
Delivery of recommendations for assessing railway equipment
Input for future reglementation and validation standards

CONCLUSION

Thank you for your attention

Questions will be welcomed