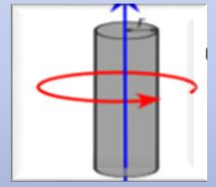
Virtual Testing for Regulation

DPPS - GTR9 experience

Irina DAUSSE (Renault – OICA) – Secretary of IWG-DPPS

TF-VT in EQOP – 1st workshop on 14th November 2023

3 cases for Virtual Test in UN-Regulations – correlation & complexity

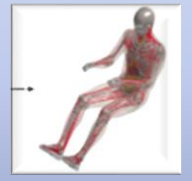


Correlation: possible with physical test (alternative)

UN-R 11 **30g inertial load**

DPPS in GTR9 – HIT determination : No physical test available

HBM kinematics “only”



EQOP More diversity to be considered

VT for biomechanical requirements => crash HBMs?

1. Current Status of Virtual Testing in UNR

VT may be used when the Technical Service accepts:
- **proof of correlation between simulation & physical test**
- **quality criteria**

C.O.P. possible by physical test

Example:
UN-R 11 (door locks & hinges) for inertial load

2.1. Option 1, Calculation

2.2. Option 2, Full vehicle dynamic test

6. Performance requirements

6.1.4. Inertial load

Each primary door latch system …**shall meet the dynamic requirements of either §6.1.4.1. and §6.1.4.2. or**

the calculation of inertial load resistance requirements of §6.1.4.3.

6.1.4.3. Each component … **can be calculated** for its minimum inertial load resistance in a particular direction. **The combined resistance to the unlatching operation must assure that the door latch system, …, will remain latched when subjected to an inertial load of 30 g in the vehicle directions specified in §6.1.4.1. and §6.1.4.2., in accordance with §7.1.1.2.**

7. Test procedure

7.1.1.2. Inertial force application :
Compliance with §6.1.4. is demonstrated in accordance with Annex 4.

Annex 4 : Inertial test procedures

1. Purpose : To determine the ability of the vehicle latch system to resist inertial loading by means of a mathematical analysis of the component parts in their true car relationship or by evaluation using a dynamic test.

2. Test procedures

2.1 or 2.2

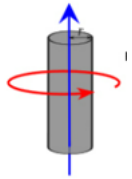
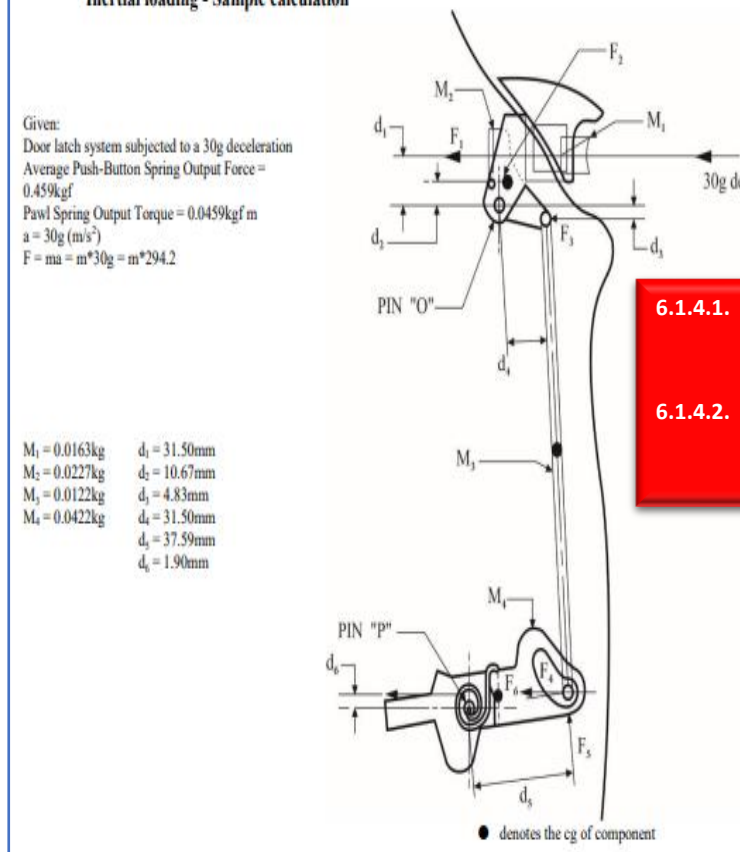


Figure 4-1
Inertial loading - Sample calculation



6.1.4.1.

6.1.4.2.

F_1 = M_1 x a - Average load on knob spring = (0.0163kg x 30g) - 0.459kgf = 0.03kgf

F_2 = M_2 x a = 0.0227kg x 30g = 0.681kgf

F_3 = $M_3/2$ x a = 0.0122kg/2 x 30g = 0.183kgf

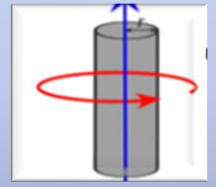
ΣM_o = $F_1 \times d_1 + F_2 \times d_2 - F_3 \times d_3$

2.1. Option 1, Calculation

2.1.1. The procedure described in this annex **provides a means for analytically determining the ability of a door latch system to withstand inertial loading**. (…) These omissions from the calculations are permissible because they provide additional factors of safety.

2.1.2. Calculation Consideration – (…) Their combined resistance… must assure that the door latch system (…) will remain latched when subjected to an inertial load of 30 g in any direction. Figure 4-1 is an example … to be considered.

3 cases for Virtual Test in UN-Regulations – correlation & complexity



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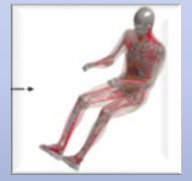


EQOP More diversity to be considered

VT for biomechanical requirements => crash HBMs?

2. DPPS
HIT determination by numerical simulation

VT must be used :
no alternative for correlation

- 5 abstraction levels,
with 3 VT checks
- quality criteria

DPPS: active bonnets for Pedestrian Protection

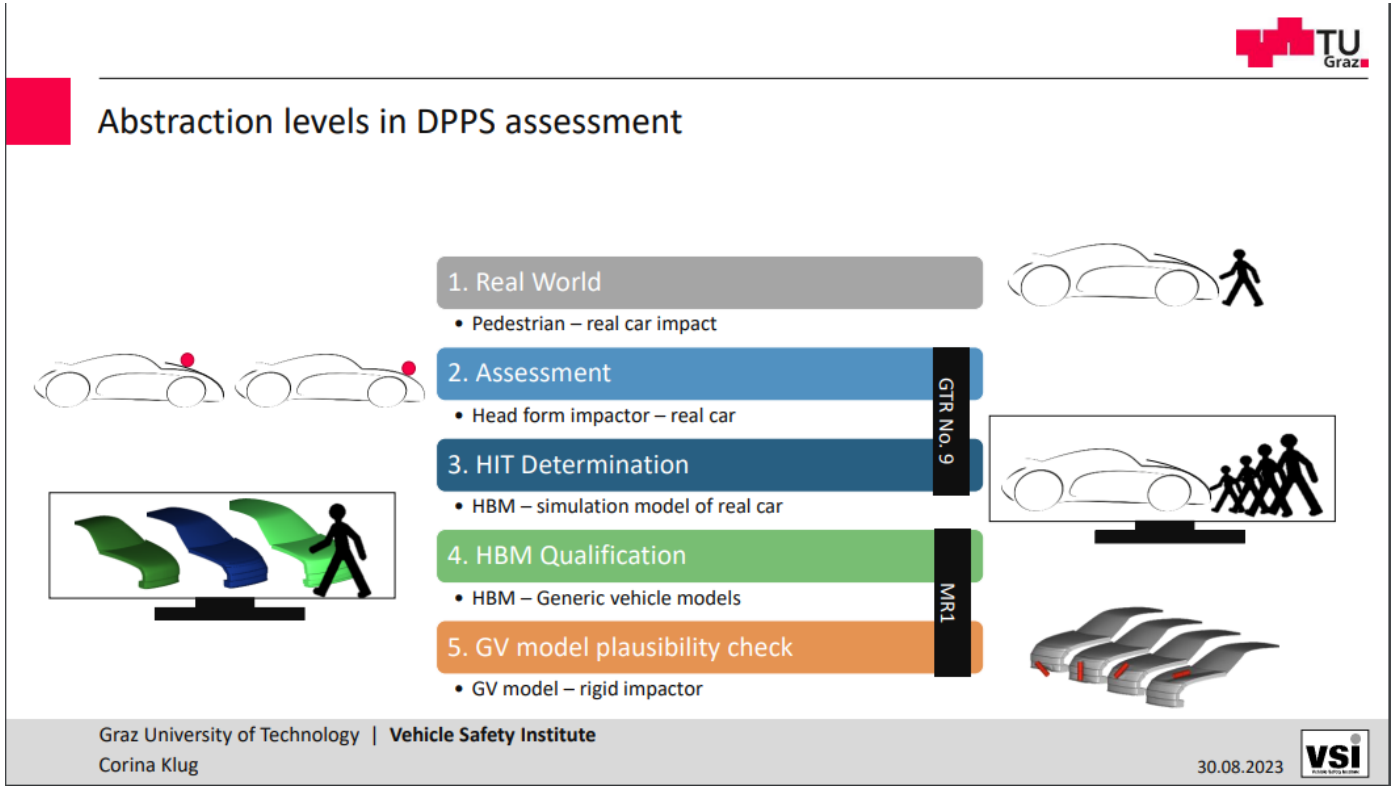
- ❖ HIC result from physical headform tests, as for passive bonnets.
- ❖ **HIT (Head Impact Time): "only" a pre-requisite** before physical tests.

➢ **HIT determination**

1. **Numerical simulation, based on HBM kinematics**

Alternatives – **Phase 2 research**

2. Physical pedestrian Dummies – Japan
3. Generic approach- USA



Alternatives – **Phase 2 research** – also challenging

II. HIT - Physical Pedestrian Dummies

- Challenge to complete the dummy family: 6y.o. , 5th female, 95th male
- Kinematic certification of the dummies needed

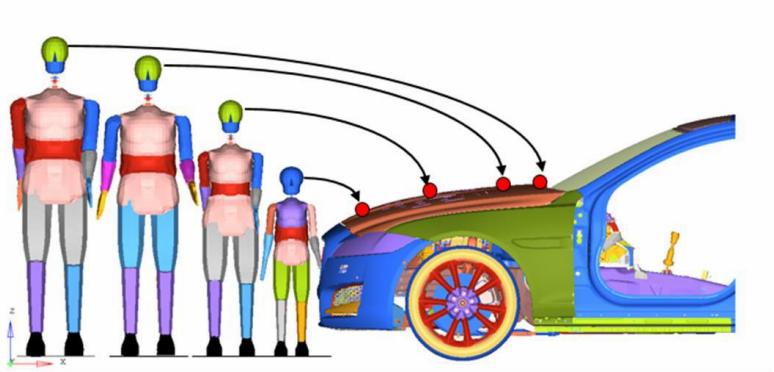
[https://www.nissan-global.com/EN/TECHNOLOGY/OVERVIEW/puehfpp.html]

III. HIT - Generic approach

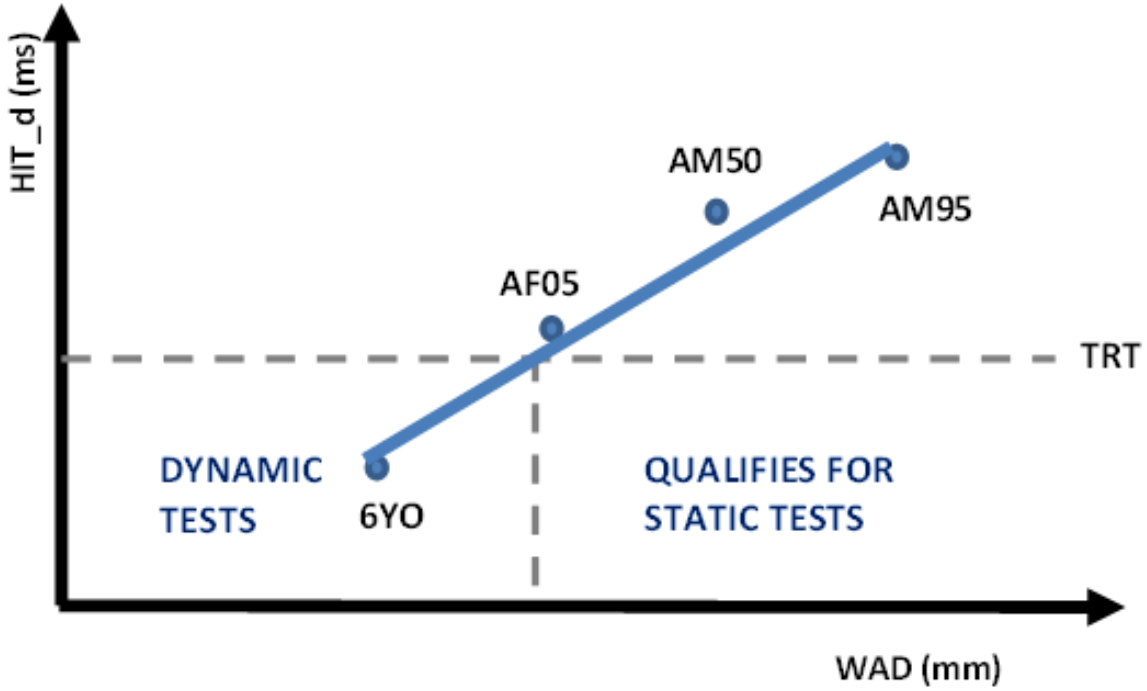
- Challenge to develop an accurate method working for all diversity of vehicle shapes & intrusions

I. HIT - Numerical Simulation

- ❑ Head Impact Time (HIT) calculated by CAE Human Body Models (HBM) on OEM vehicle
  - HIT-graph to decide if static or dynamic testing
- ➢ HBM certification: adaptation of Technical Bulletin 24 (TB024) from Euro NCAP
- ➢ maintenance of CAE Generic Vehicle Models - TUG on UN website



Dummy	Time to contact (ms)	Wrap Around Distance (WAD) mm
6YO	64.0	965.1
5%tile	85.0	1403.7
50%tile	117.0	1818.5
95%tile	132.0	1979.5

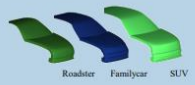


- ❑ Challenge for Self Certification: check in-house simulations with OEM vehicle models & HBMs

IWG-DPPS-25-05_Documentation_of_Generic_Vehicle_Models

MR 1 – Addendum 5: Specifications for the Qualification of Human Body Models for Pedestrian HIT Determination for DPPS (DPPS tools)

GV Models



Specification and tools needed for GV Model plausibility check

Corridors for GV Model plausibility check
Loadcase 1

Qualification Process of Human Body Models for Pedestrian HIT Determination

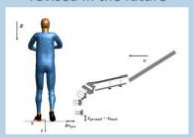
Reference to Amendment 3 of GTR No 9

Specification for HBM qualification simulations

Corridors for HBM Qualification for Use in DPPS

GV Type	Velocity (km/h)	HIT (ms)		HCx (mm)		HCz (mm)	
		Min	Max	Min	Max	Min	Max
FCR	30	152	197	-1438	-1005	1019	1117
	40	127	150	-1489	-1105	1006	1158
	50	107	121	-1504	-1179	1024	1169
RDS	30	163	199	-1574	-1104	931	1125
	40	133	156	-1659	-1191	931	1178
	50	112	127	-1665	-1283	981	1183

Documentation + Guideline what needs to be done if corridors shall be revised in the future

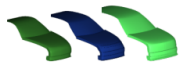


HBM Validations (comparison with PMHS tests) – „Qualification" of Human Body Models to be used for corridor definition

	HIT (ms)		ABCx (mm)		HCx (mm)	
	Min	Max	Min	Max	Min	Max
Reference from PMHS Tests	117	159	-1653	-1402	1020	1271
LSBHMC M50-PS v5.3.4 LS-DYNA MPP R10.2		126.6		-1452		1160
LSBHMC M50-PS v1.0 Radioss 2019.2.0		139.4		-1614		1181
LSBHMC M50-PS v5.33 R1.09 VPS 2019.0.4		120.2		-1500		1186
LSBHMC M50-P v5.3.4 LS-DYNA MPP R10.2		140.7		-1503		1182
ZAMA pedestrian_AM50 ver6.2.1, LS-Dyna MPP R10.0		141.9		-1586		1191
THUMS v4.02 TH024 (05/22) LS-Dyna MPP		141.6		-1622		1223

- Challenges for Type Approval:
  - Quality criteria of the OEM vehicle models & simulations & HBMs : **Annex 2**
  - How to proceed for Conformity of Production & Market Surveillance ?
  - Intellectual property…

Building Blocks



Generic Vehicle Models available on UNECE website – MR1

Human Body Models (openly available or by suppliers)

Vehicle Simulation Models with DPPS of Vehicle Manufacturer

Finite Element Software

(supplied by code-houses to Industry)

1. GV Plausibility check
2. Human Body Model qualification
3. HIT vs. WAD determination
4. Use HIT for DPPS decision

1.3. General Requirements

1.3.1. It shall be ensured that the HBMs used in this Annex comply w requirements within Addendum 5 of Mutual Resolution No.1 (M.R.1 qualification results shall be documented as specified in Addendu M.R.1.

1.3.2. Only those HBM statures selected according to paragraph 2.2. of this shall be qualified.

1.3.3. The pedestrian HBM that is qualified is the very same model as us HIT determination simulations. This applies to:

(a) Version of the HBM;

(b) Node-Position of every single node of the HBM;

(c) Identical material cards (including fracture mode), c

1.3.4. Furthermore, all simulations (qualification and HIT be performed with consistent settings. This applies to:

(a) Solver-Version and type (e.g. processi parallelisation);

(b) The time-step used for simulations;

3. Documentation

3.1. General

The following information shall be documented:

(a) Date of report;

(b) Name of car manufacturer;

(c) Type and release version of software (FE-software package name, revision and version);

(d) Name and version of the HBM;

(e) Specification of car.

Images showing the front view and side view of the pedestrian, at t0 and at the time of head impact shall be added to the report.

3.2. Consistency with qualification simulations

For all simulations Table 2-1 shall be filled in.

Table 2-1
Check of consistency between qualification and HIT determination simulations

Checklist for simulation settings	Consistent between qualification and HIT determination simulations:
Identical HBM	Y/N
Solver Version	Y/N
Timestep	
All other	

3.4. Results of HIT determination simulations

For those HBMs that are selected according to paragraph 2.2. of this Annex, the computed HIT-Values and corresponding WADs have to be filled into the following Tables 2-3 and 2-4.

If HIT_d ≥ TRT for all HBMs, simulations on the undeployed DPPS are not required.

Table 2-3
HIT_d Simulations on Deployable Pedestrian Protection Systems in Deployed Mode

HBM	WAD (mm)	HIT_d (ms)
6YO		
AF05		
AM50		
AM95		

Table 2-4
HIT_s Simulations on Deployable Pedestrian Protection Systems in Undeployed Mode

HBM	WAD (mm)	HIT_s (ms)
6YO		
AF05		
AM50		
AM95		

For each simulation, the following diagrams shall be documented:

(a) ACx and HCx as a function of time;

2.3. Output Requirements

It shall be confirmed that the following outputs have been generated from each simulation, time history curves of:

(a) x and z coordinate of HC and AC in the global coordinate system;

(b) x displacement of vehicle CoG in the global coord

(c) Resultant acceleration of HC;

(d) Contact forces (between vehicle and HBM extremities, vehicle and HBM head and total cont

(e) Total hourglass and internal energies of the total

(f) Mass increase.

All shall be plotted every 0.1ms or less.

Furthermore, animations of the simulations shall be g output interval of 1ms.

2.4. Quality Che

The followin

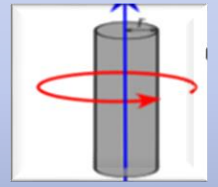
(a) Cont start;

(b) Total

Table 2-2
Quality Checks

Verification evaluation criteria			
Coefficient of friction between Vehicle an			
Head centre of gravity is positioned at vel centreline	Y=0 mm		Y/N
Contact force between HBM and vehicle at simulation start	0		Y/N
Change in total energy throughout simulation	≤15%		Y/N
Amount of hourglass energy relative to total energy	≤10%		Y/N
Artificial mass increase relative to total mass of the setup	≤3%		Y/N

3 cases for Virtual Test in UN-Regulations – correlation & complexity



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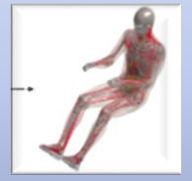
Next step



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Thank you !

Any questions ?