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TOWARDS A REGULATORY FRAMEWORK FOR THE USE OF STRUCTURAL NEW MATERIALS IN RAILWAY PASSENGER AND FREIGHT CARBODYSHELLS

Fire, noise and lightweight materials

Final Conference REFRESCO

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SEVENTH FRAMEWORK PROGRAMME

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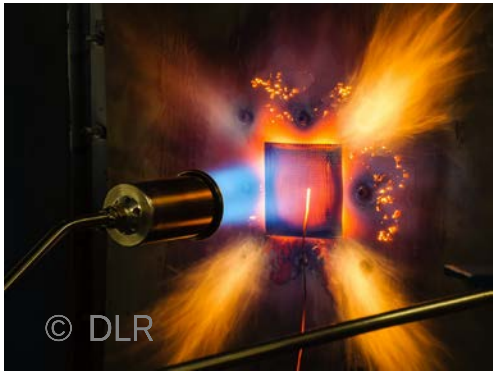
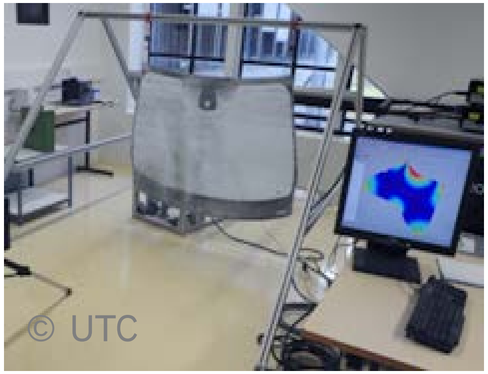
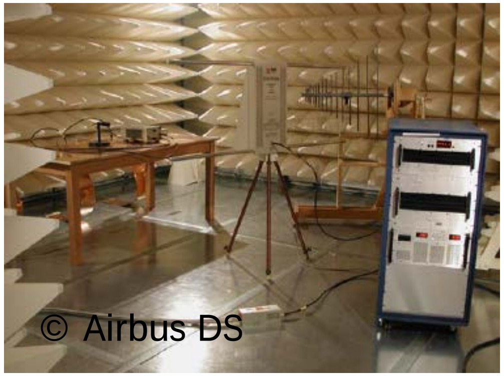
Aim and Objectives of WP3

- Three parallel topics: FST / NVH / EMC
  - T3.1 Fire & Smoke (UNEW, Dupont, Bombardier, DLR)
  - T3.2 Noise & Vibration (UTC, Bombardier, DLR)
- Survey and recommendation of composite carbody-shell materials for railway applications concerning FST and NVH.







Background
3.1 Fire, Smoke and Toxicity (FST)

Components	EN 45545
Sides of external body shell	R7
Sides of internal body shell	R1
Cab housing	R7
Roof of external body shell	R8
Under frame of external body shell	R7
Exterior surfaces of gangways	R7

Operation category	Design category			
	N	A	D	S
1	HL1	HL1	HL1	HL2
2	HL2	HL2	HL2	HL2
3	HL2	HL2	HL2	HL3
4	HL3	HL3	HL3	HL3

Example:
OC 3 = Intercity – Tunnel Operation
DC D = Double decked vehicles

Requirement	Test method	Parameter unit	Max/min	HL1	HL2	HL3
R7	T02 ISO 5658-2 Critical Flux at Extinguisments Lateral Flame Spread	CFE kWm^{-2}	Min	20	20	20
	T03.01 ISO 5660-1: $50kWm^{-2}$ Cone Calorimetry	MARHE kWm^{-2}	Max		90	60
	T10.03 EN ISO 5659-2: $50kWm^{-2}$ Maximum Specific Density Smoke Smoke density test	D_s max. dimensionless	Max		600	300
	T11.01 EN ISO 5659-2: $50kWm^{-2}$ Conventional Index of Toxicity (ISO 5659-2+EN45545 -Annex C)	CIT_G Dimensionless	Max		0,9	1,5

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Results and Conclusions (1/3)
3.1 FST


LOGO Headers
Certificate of accredited lab

- Currently there is a lack of homologated structural composite materials in railway.
- EN45545 test values mainly for composites used in interior application.

	HTS-145 UD Carbon	Category & Target			
Resin Content	46%	R1		R6	
Laminate thickness	2.0mm	HL2	HL3	HL2	HL3
Cone calorimetry - MAHRE (kW/m2)	57.1	≤90	≤60	≤90	≤60
Smoke density - Ds4	220	≤300	≤150		
Smoke density - VOF4	422	≤600	≤300		
Smoke density - Ds Max	246			≤600	≤300
Toxic Gas - CIT_g at 8mins	0.11	≤0.9	≤0.75	≤1.8	≤1.5
Flame spread - critical heat flux (kW/m2)	37.5	≥20	≥20	≥20	≥20

Epoxy/Carbon, Cytec MTM348FR [© Cytec]

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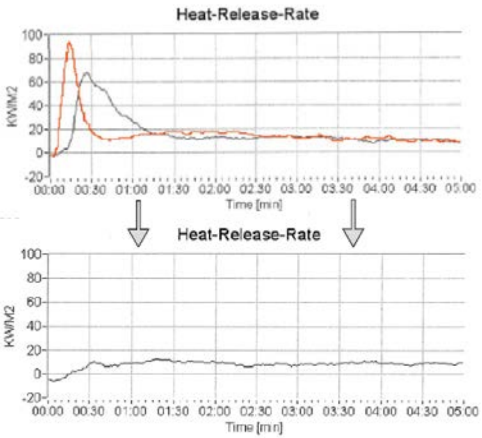
Results and Conclusions (2/3)
3.1 FST

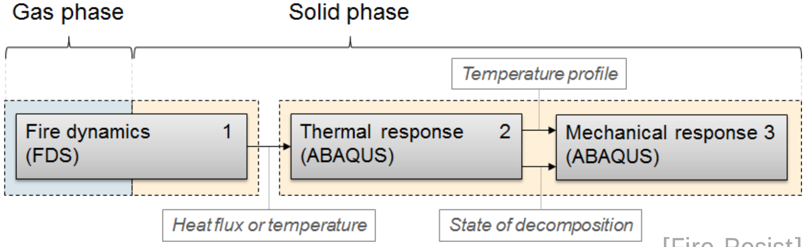
- General guidelines on FST-compliant material choice:
  - Polymers with a high thermal stability, a low release rate of flammable volatile components and high charring.
  - There are alternatives to Epoxy resins with better FST properties, e.g. CE and PB.
  - Flame retardants as filler for fire sensitive matrix systems like epoxy, e.g. APP.
  - Coatings or Layers of flame retarding or non-flammable materials (barrier) to keep away the fire from entering the structural area.



Synergy effects [DLR]

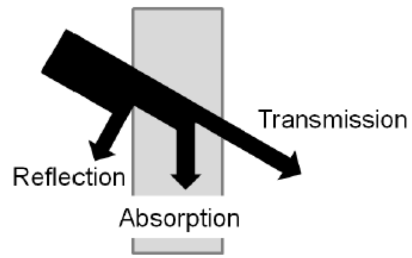
Results and Conclusions (3/3)
3.1 FST

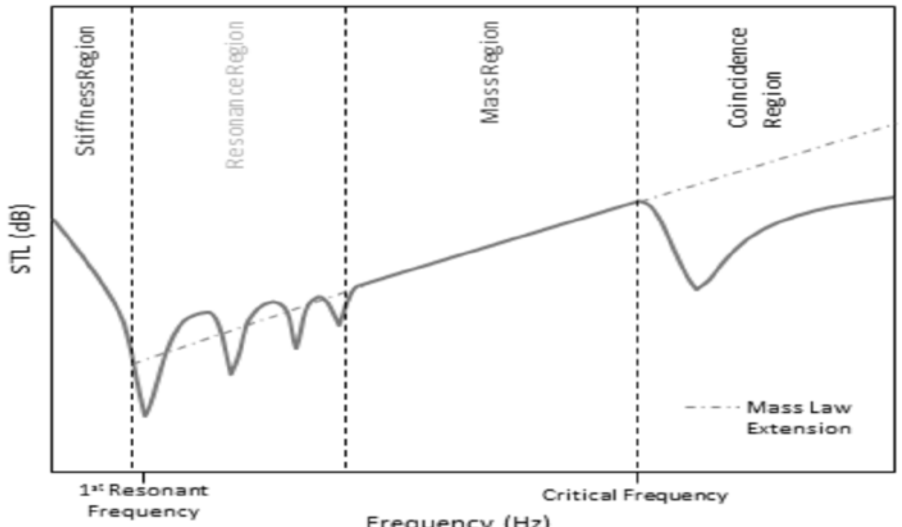
- Structural integrity in case of fire
  - Verification through analytical models using coupling tools between FE and CFD models (-> FIRE-RESIST project)
  - Fire test of intermediate scale is advisable to validate material models and FE/CFD model results.
  - Fire test of full scale is advisable for the most critical section of the structure.



[Fire-Resist]

Background
3.2 Noise, Vibration and Harshness (NVH)

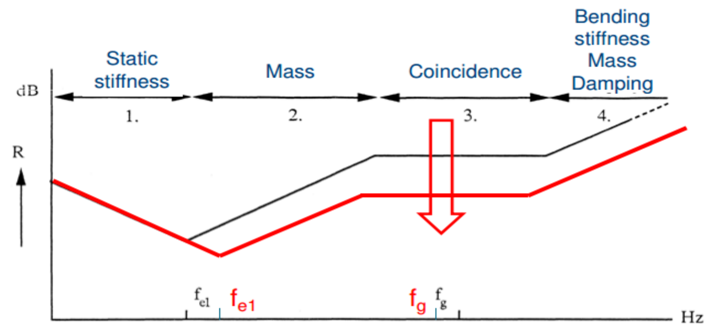




[Griese2012]

Challenges
3.2 NVH

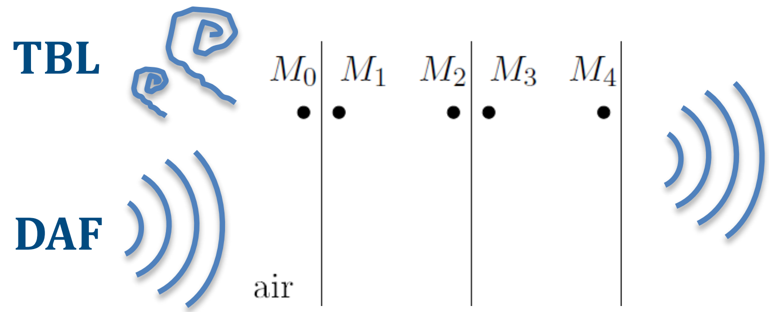
- Due to the high stiffness of composite panels the resonance controlled region is shifted towards the medium frequency range and the panel can easily vibrate and radiate noise.
- The critical frequency (f_g) shifts to a lower frequency in comparison with a metallic panel. This can decrease the transmission loss for audible frequencies.
- The bandwidth of the coincidence zone is wider due to different kind of wave propagating in the skins and the core materials.
- Noise reduction gets worse with less weight and higher stiffness.



Case Study
3.2 NVH

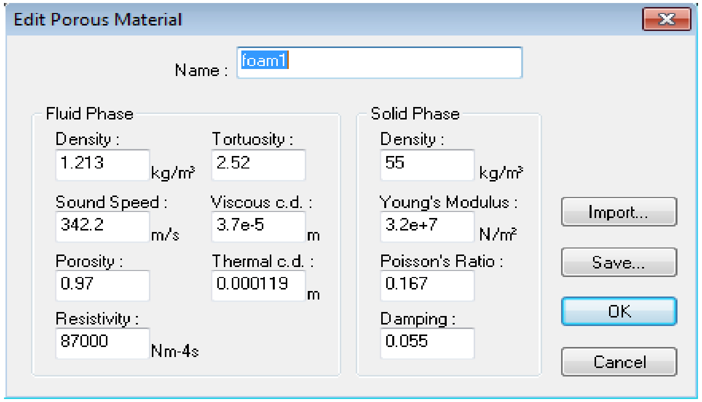
Sandwich	Excitation	Evaluation
CFRP – Toplayer	Diffuse Acoustic Field (DAF) Turbulent Boundary Layer (TBL)	transmission loss, radiated power, modal density
Resin: Epoxy		
top-layers: UD or quasi-isotropic		
Foam: Airex T90		
Honeycomb: Aramid (alternative: Aluminium*)		
GFRP – Toplayer		
Resin: Epoxy		
top-layers: quasi-isotropic		
Foam: Airex T90		
Honeycomb: Aluminium (alternative: Aramid)		

- Transfer Matrix Method (TMM)
- Software: Nova



- Material properties
  - solid for skin and honecomb
  - poroelastic for foam

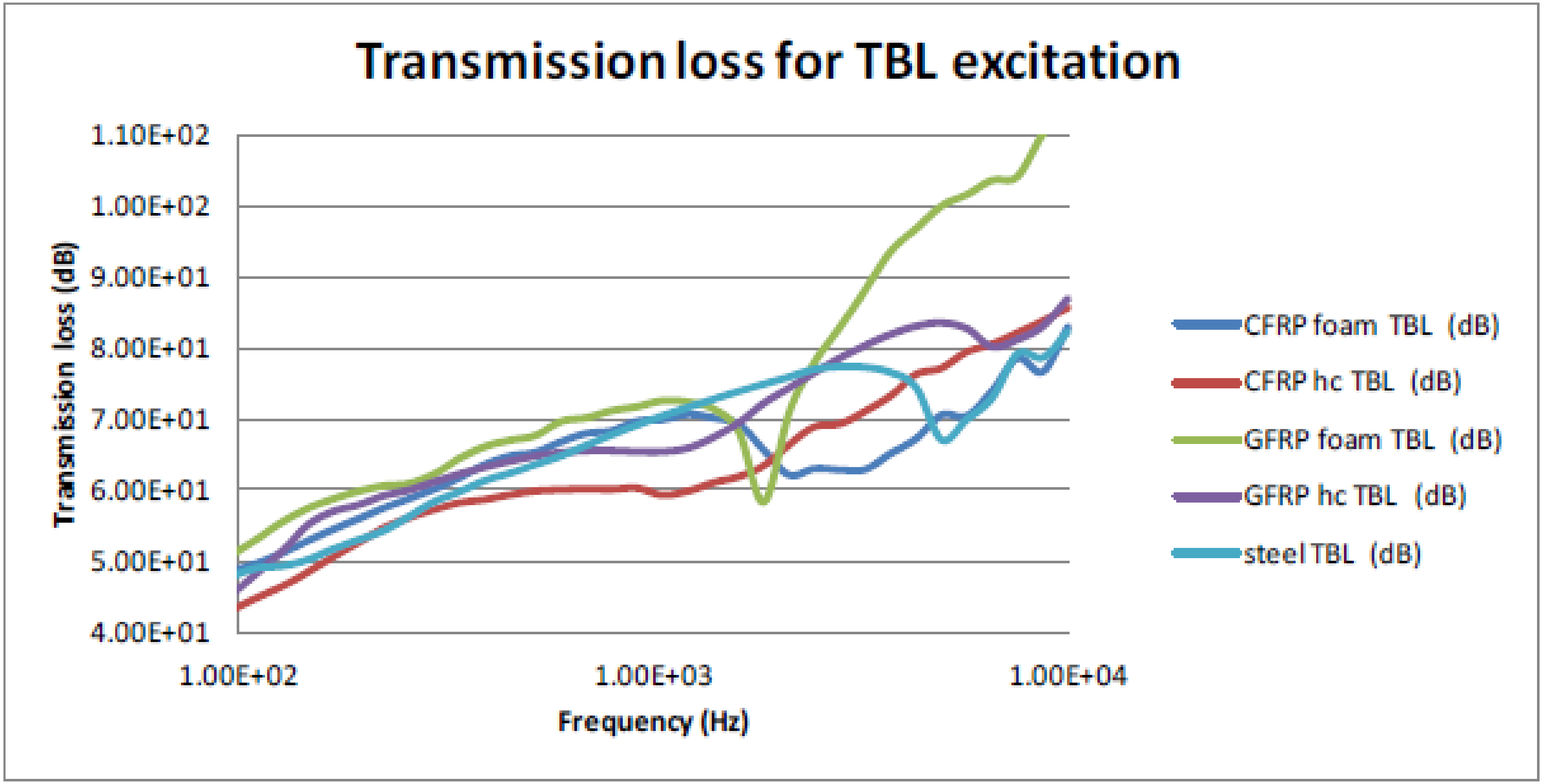
	Young modulus (Gpa)			Shear modulus (Gpa)			Poisson's ratio			density (kg/m^3)	damping	thickness(m)
material	E1	E2	E3	G12	G23	G13	v12	v23	v13			
CFRP	46.6	44.3	44.3	4.4	4.4	4.4	0.15	0.15	0.15	1725	0.1	0.0039
GFRP	25.5	22.9	22.9	3.41	3.41	3.41	0.1	0.1	0.1	1950	0.1	0.0039
HC	0.17	0.17	0	0.042	1.48	1.48	0.996	0.3	0	55	0.01	0.06
steel	200	200	200	75	75	75	0.32	0.32	0.32	7841	0.007	0.0025



- Composite panel NVH properties

skin	core	skin	Physical phenomena	frequency Hz
CFRP	Foam	CFRP	Fc	2100
CFRP	HC	CFRP	Fc	1200
GFRP	Foam	GFRP	F2p	1840
GFRP	HC	GFRP	Fc	1390
Steel			Fc	5700

Case Study Results
3.2 NVH



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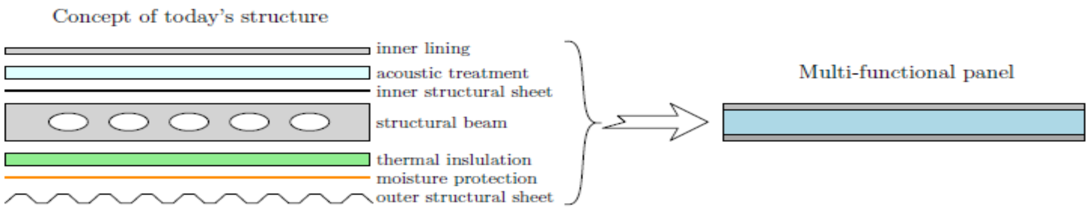
Recommendations
3.2 NVH

- The common principle of using a heavier structure cannot be applied.
- Optimize the multifunctional design, e.g. for an easier use of connectors with good damping characteristics to reduce vibration travelling into the panels
- Dissipate vibro-acoustic energy by damping effect.
- Optimize lay-up angle to increase the first Eigen frequency that is directly in relation with ride comfort.
- Change the geometry of unit cell in honeycomb
- Active / Smart Structures (sensors and actuators)



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Thank you for your attention!

D3.1 Proposal of FST strategy for structural composite parts based on material properties (UNEW)
D3.2 Proposal of NVH strategy for structural composite parts based on material properties (UTC)

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