LEON-T Project:

Modeling the performance of an airless truck tyre prototype analysing stiffness with FEA

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19th March, 2024

PUBLIC

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WHAT IS LEON-T

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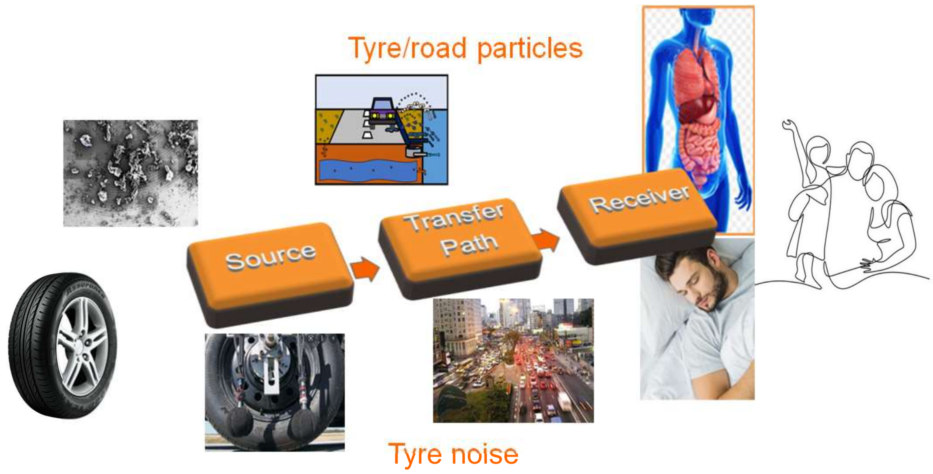
LEON-T investigates the relationship between the source, the transmission/fate and the effect on the receiver of tyre related particles and noise.



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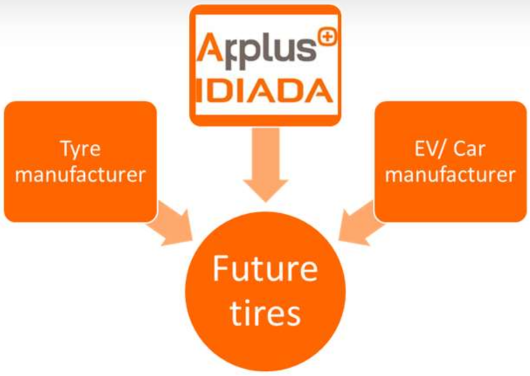


LEON-T

Low particle Emissions and lOw Noise Tyres

Image courtesy: University of Gothenburg

AIRLESS TYRE
DESIGN AND MATERIAL PROPERTIES

PUBLIC 5

Component	Type	Properties
Rim and spokes	51CrV4 steel (quenched and annealed at 400°C)	• Yield – 1455 MPa • Ultimate – 1700 MPa • E – 2.1E5 MPa • Poisson's ratio – 0.3 • Structural damping – 1% [8]
Tread	100% natural rubber	Hardness - 74 ShA
Composite fiber ring	Glass fiber reinforced plastic* (GFRP)	• Quasi-isotropic lay-up of 13 layers • Density - 600 g/m2 plain weave. • Layer thickness - 0.54 mm (approx.) • Stacking sequence +-45° outermost and 0°-90° alternating.

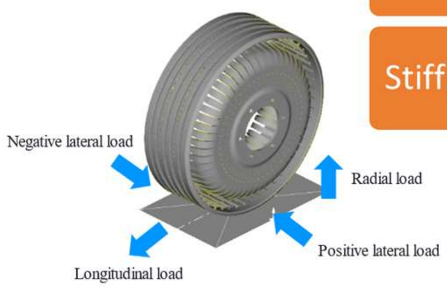
*In simulation, composite fiber ring is modelled as linear isotropic material

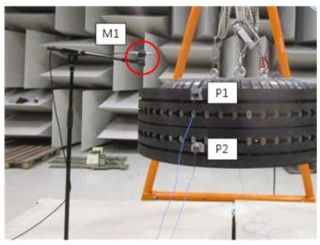
AIRLESS TYRE
PERFORMANCE STUDIES

PUBLIC 6

Tire behaviour study

Static	Dynamic	
Stiffness	Modal	Noise





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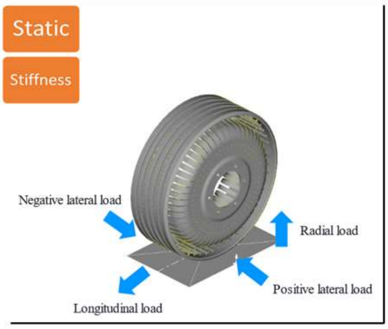
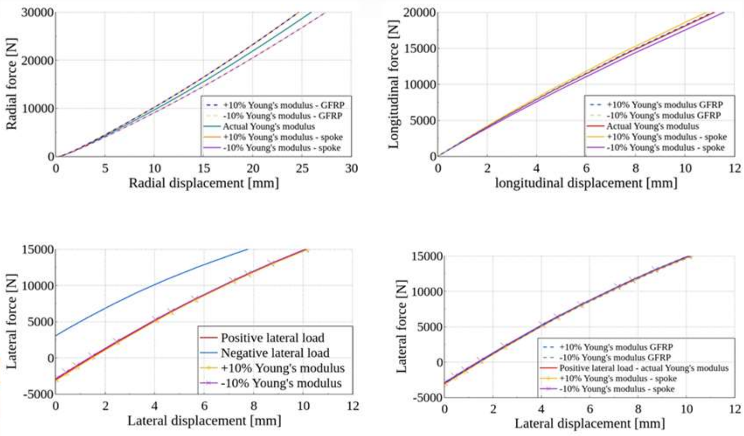
PERFORMANCE STUDIES: STATIC



Load Type	Value (kN)	Stiffness (N/mm)	
		Airless tire	Conventional tire
Radial	30	1500	1000-1400
Lateral (+Radial)	9	1300	500
Longitudinal (+Radial)	9	1100	500



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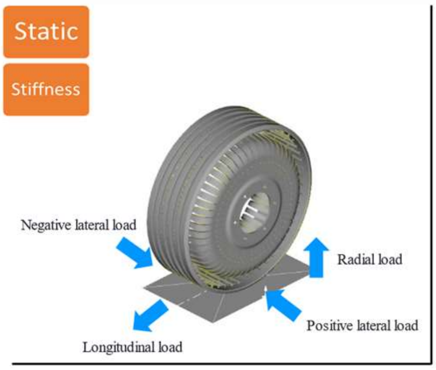
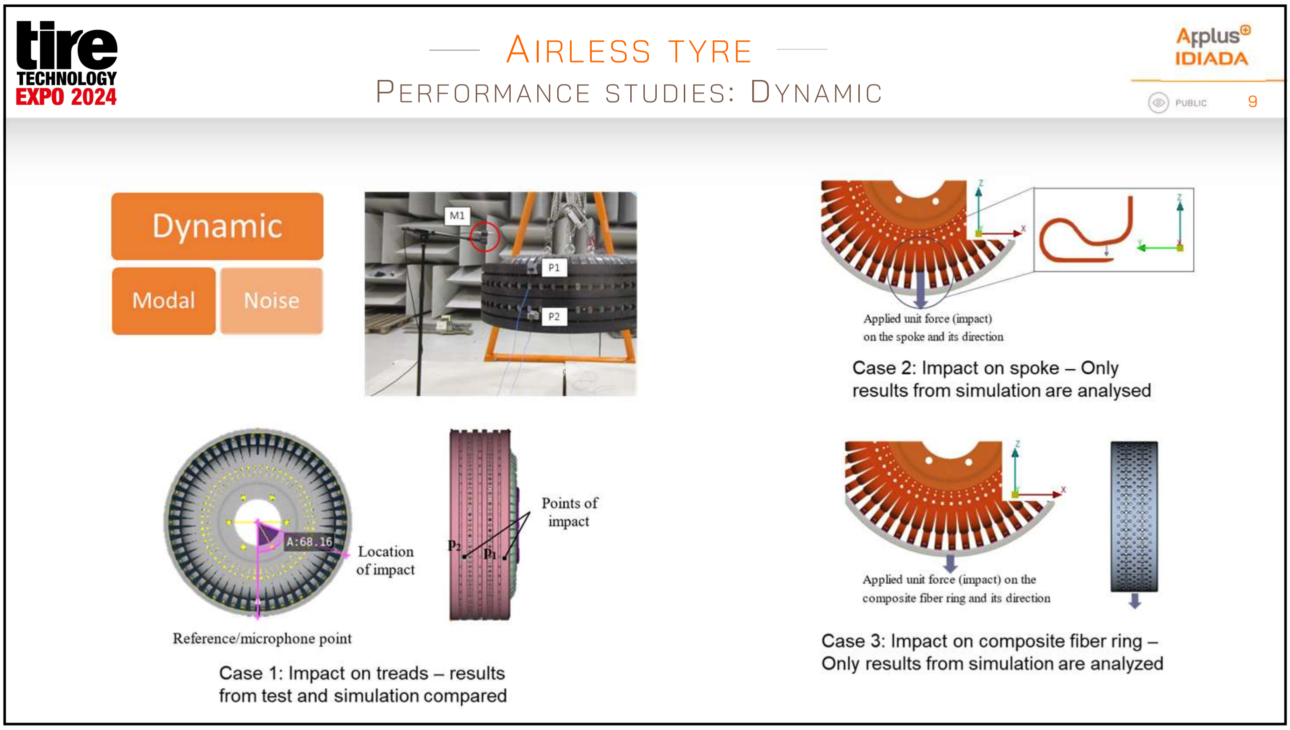
PERFORMANCE STUDIES



Key takeaway:

Young's modulus of:	Radial force	Lateral force	Longitudinal force
Composite fiber ring	Positive correlation	No significant effect	No significant correlation
Spoke	Positive correlation	No significant effect	Positive correlation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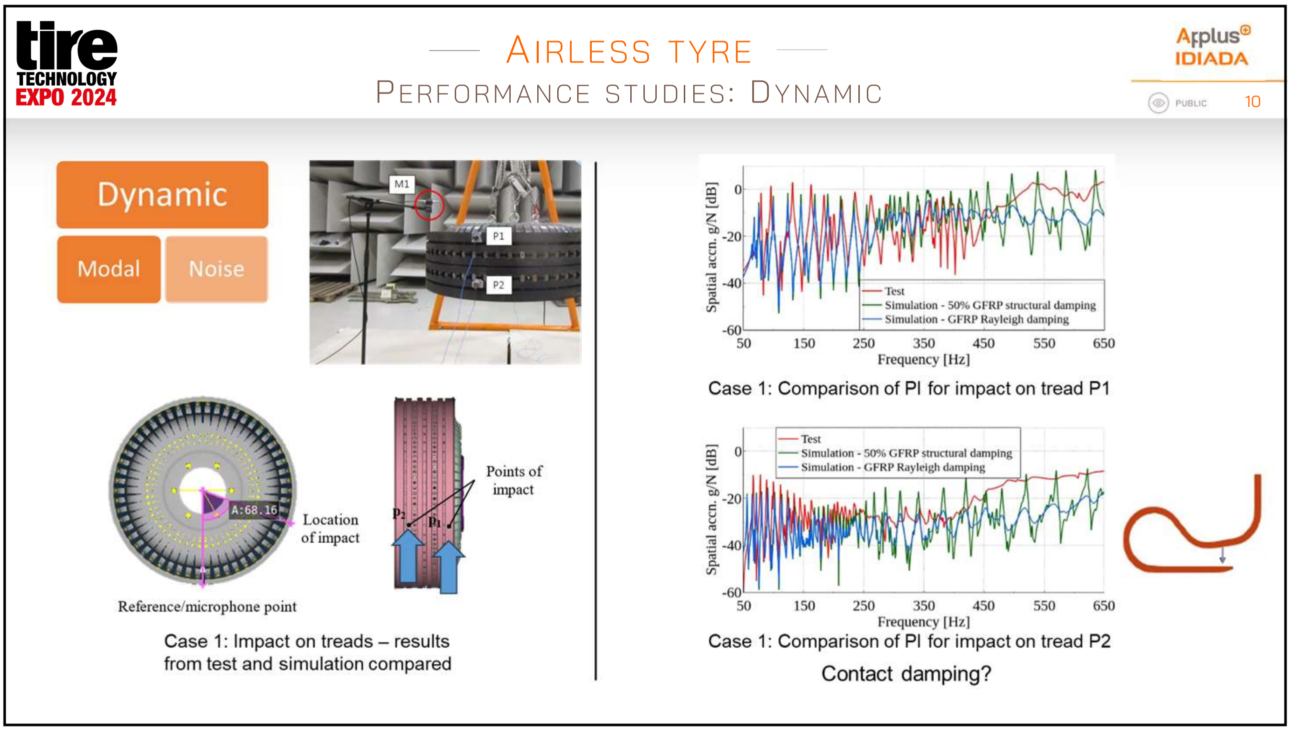
Dynamic
Modal
Noise
M1
P1
P2
Applied unit force (impact)
on the spoke and its direction
Case 2: Impact on spoke – Only results from simulation are analysed
A:68.16
Location of impact
Points of impact
Reference/microphone point
Case 1: Impact on treads – results from test and simulation compared
Applied unit force (impact) on the composite fiber ring and its direction
Case 3: Impact on composite fiber ring – Only results from simulation are analyzed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Dynamic
Modal
Noise
M1
P1
P2
A:68.16
Location of impact
Points of impact
Reference/microphone point
Case 1: Impact on treads – results from test and simulation compared
Spatial accn. g/N [dB]
Frequency [Hz]
Test
Simulation - 50% GFRP structural damping
Simulation - GFRP Rayleigh damping
Case 1: Comparison of PI for impact on tread P1
Case 1: Comparison of PI for impact on tread P2
Contact damping?

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Airless tyre

Performance studies

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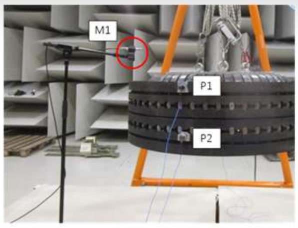
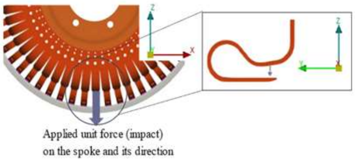
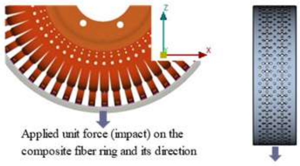
Dynamic

Modal | Noise

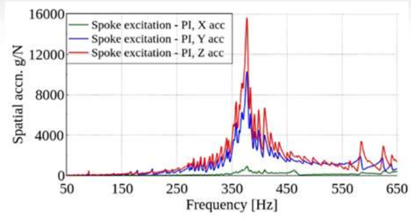




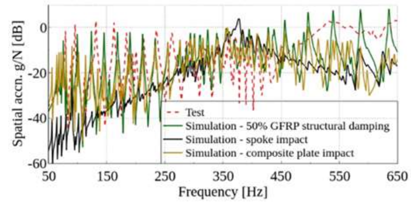
Case 2: Impact on spoke – Only results from simulation are analysed



Case 3: Impact on composite fiber ring – Only results from simulation are analyzed



Case 2: PI for impact on spoke (only simulation)



Case 3: PI for impact on composite fiber ring (only simulation)

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Airless tyre

Performance studies: Dynamic

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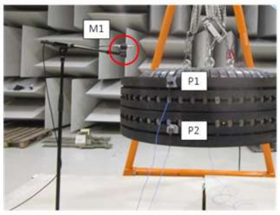
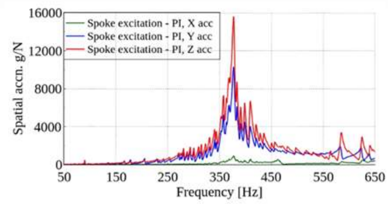
Dynamic

Modal | Noise

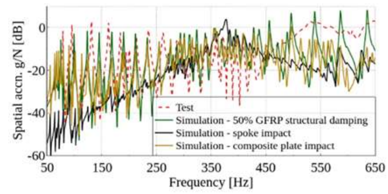


Take aways:

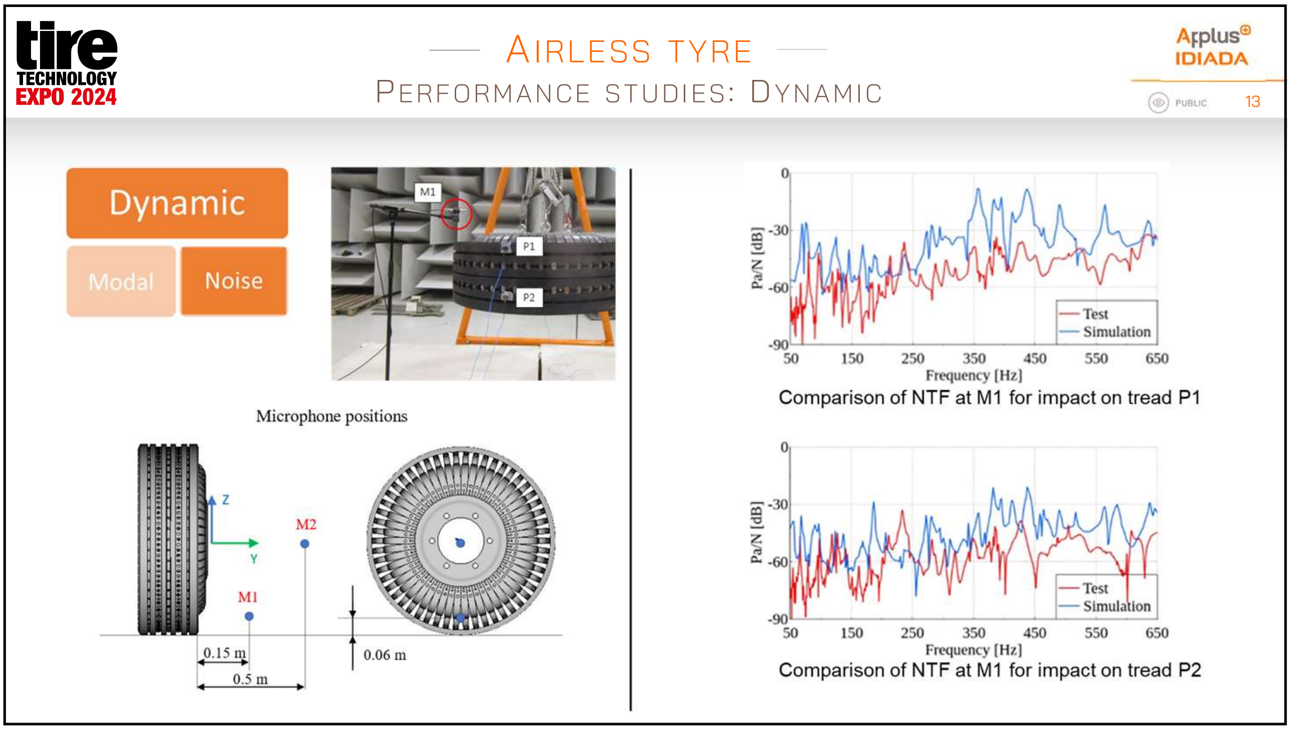
- Reliability for impact on P1 – 450 Hz and P2 – 250 Hz – contact damping at P2 can be the key factor that needs to be considered for attenuating the amplitude beyond 250 Hz
- Composite plate has the maximum contribution on the modal behaviour of the tire



Case 2: PI for impact on spoke (only simulation)



Case 3: PI for impact on composite fiber ring (only simulation)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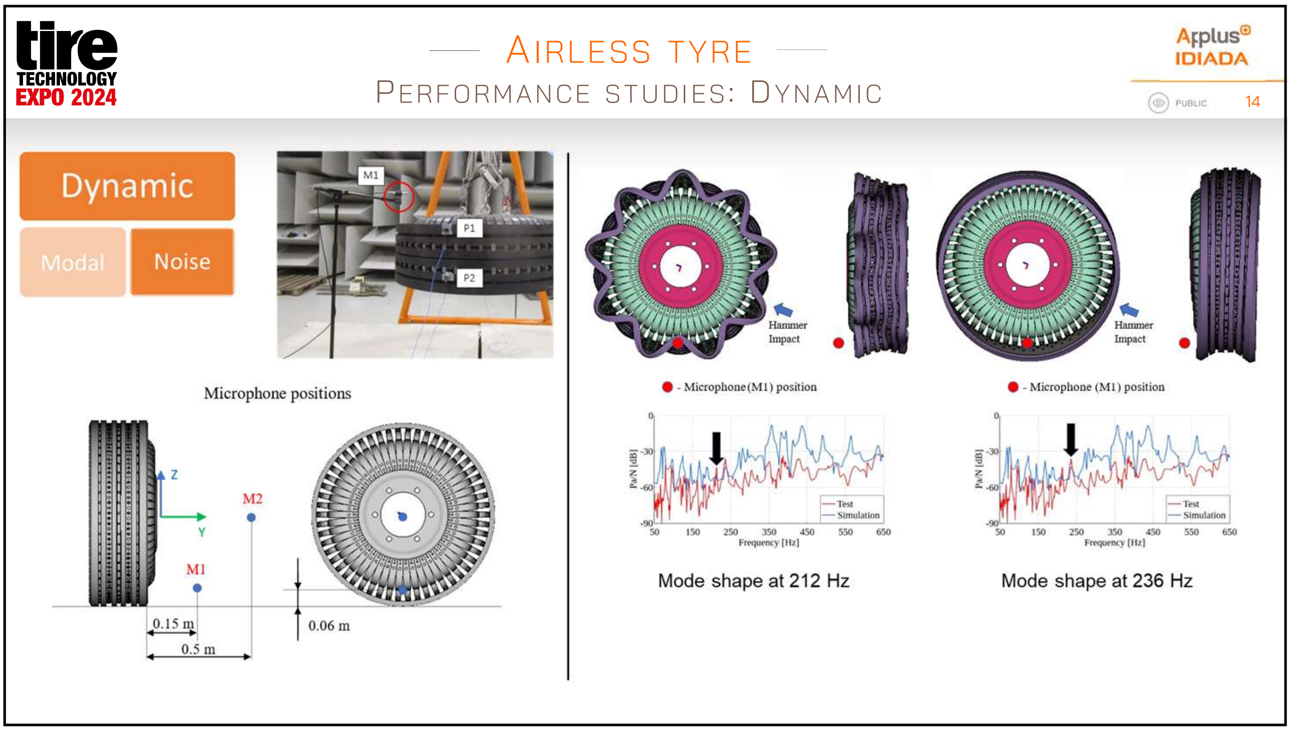
Dynamic
Modal
Noise
M1
P1
P2
Microphone positions
Z
Y
M2
M1
0.15 m
0.5 m
0.06 m
Pa/N [dB]
Frequency [Hz]
Test
Simulation
Comparison of NTF at M1 for impact on tread P1
Comparison of NTF at M1 for impact on tread P2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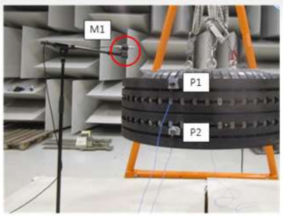
Dynamic
Modal
Noise
M1
P1
P2
Microphone positions
Z
Y
M2
M1
0.15 m
0.5 m
0.06 m
Hammer Impact
- Microphone (M1) position
Mode shape at 212 Hz
Mode shape at 236 Hz

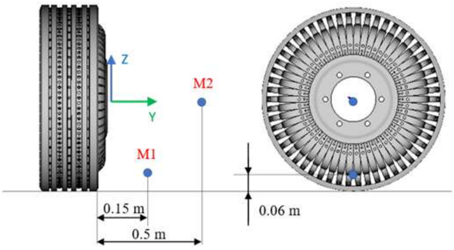
AIRLESS TYRE
PERFORMANCE STUDIES: DYNAMIC

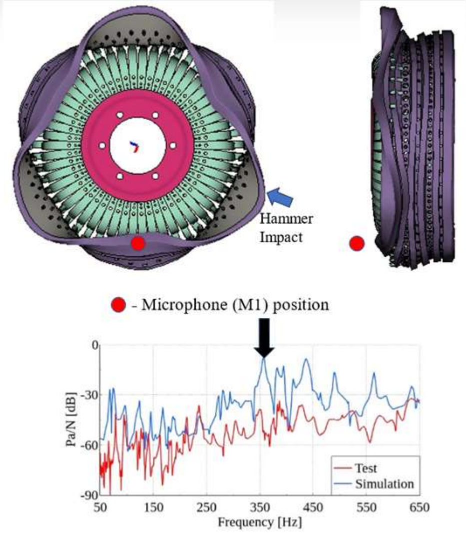
Dynamic

Modal | Noise



Microphone positions





Mode shape at 357 Hz

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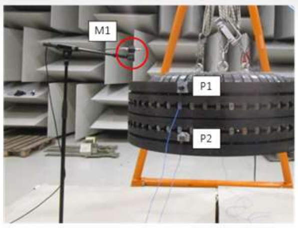
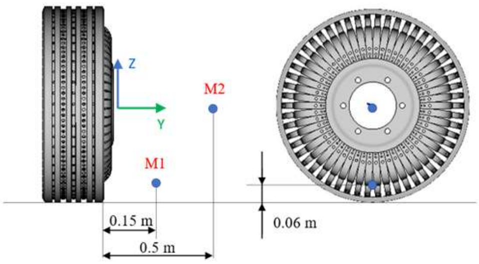
PERFORMANCE STUDIES: DYNAMIC

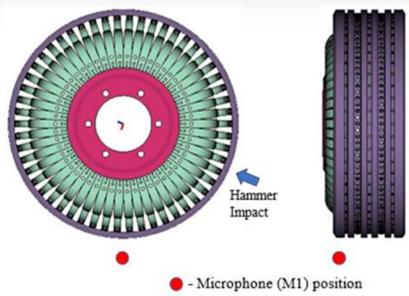
Dynamic

Modal | Noise



Microphone positions





Recommended microphone placement for NTF measurements in airless tires.

Key take aways:
- NTF levels match in test and simulation for non-complex mode shape
- Complex mode shape – Compressions and rarefactions of the spokes is difficult to be picked up by the microphone
- Recommended microphone position – along the circumference of the tire

SUMMARY

- Airless tyre design comprised of:
  - Spokes
  - Composite ring
  - Rim
  - Tread
- Materials:
  - glass fiber reinforced plastic (GFRP) for ring
  - rubber (tread)
  - steel material
- In simulation, composite fiber ring is modelled as linear isotropic material

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SUMMARY

Static simulations

- Young's modulus of GFRP and spokes have positive correlation on radial and longitudinal stiffness of the tyre
- The influence is not significant on lateral stiffness

Dynamic simulations

- Modal - Composite plate has the maximum contribution on the modal behaviour of the tyre
- Noise - NTF levels match in test and simulation for non-complex mode shape
- Noise - Complex mode shape – Compressions and rarefactions of the spokes is difficult to be picked up by the microphone
- Noise - Recommended microphone position – along the circumference of the tyre

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THANK YOU FOR YOUR KIND ATTENTION

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