Modal testing and finite element modelling of a reduced-sized tyre for rolling contact investigation

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Context

- Over 50 km/h, rolling noise predominates over other road noise sources.
- Dynamic tyre/road contact, a major rolling noise source, needs a better understanding.
- A cylindrical test rig incorporating a go-kart tyre will be used for this purpose.
- Modal testing was done to provide a realistic numerical model of the tyre for contact simulation.

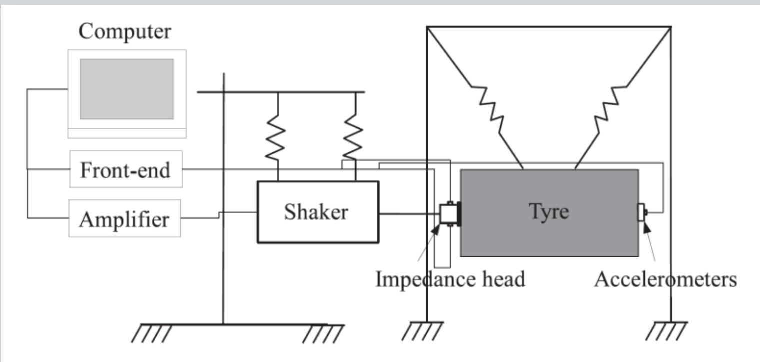
Context

- Advantages of using a go-kart tyre:
  - easier to manipulate in laboratory
  - less inertial effects during rotations
  - simpler structure for modelling

http://www.kartpartsdepot.com/Go_Kart_Wheels_s/1850.htm

- Type of go-kart tyre:
  - commercial slick tyre
  - 10-4.50-5, i.e. 114/55R5 in ISO
  - tread: rubber layer
  - carcass: rubber-coated nylon layers
  - bead: reinforcement by steel wires
  - maximal inflation pressure: 3.9 bars

Modal testing – Experimental set-up



Schematic drawing and photo of the experimental set-up

- Single-Input Multiple-Output approach
- Suspended tyre radially drived by a shaker
- 1 impedance head for direct force and acceleration measurements
- 5 accelerometers for transfer acceleration measurements
- 528 measurement points: 11 points on each outer contour of 48 cross sections

Modal testing – Measurements

- Input signal: random signal swept between 0 and 6000 Hz
- Complex FRFs (Frequency Response Functions) calculated
- Inflation pressure = 1 bar: measurements over the whole tyre
- Validation of geometrical symmetries:
  - symmetry about the median line around the tyre
  - symmetry about the excitation direction
- Inflation pressure = 0 and 2 bars: measurements on a quarter of the tyre (half of the upper part)

Modal testing – Modal analyses

- Modal parameters (eigenfrequencies and damping ratios) extracted using the global RFP (Rational Fraction Polynomial) method

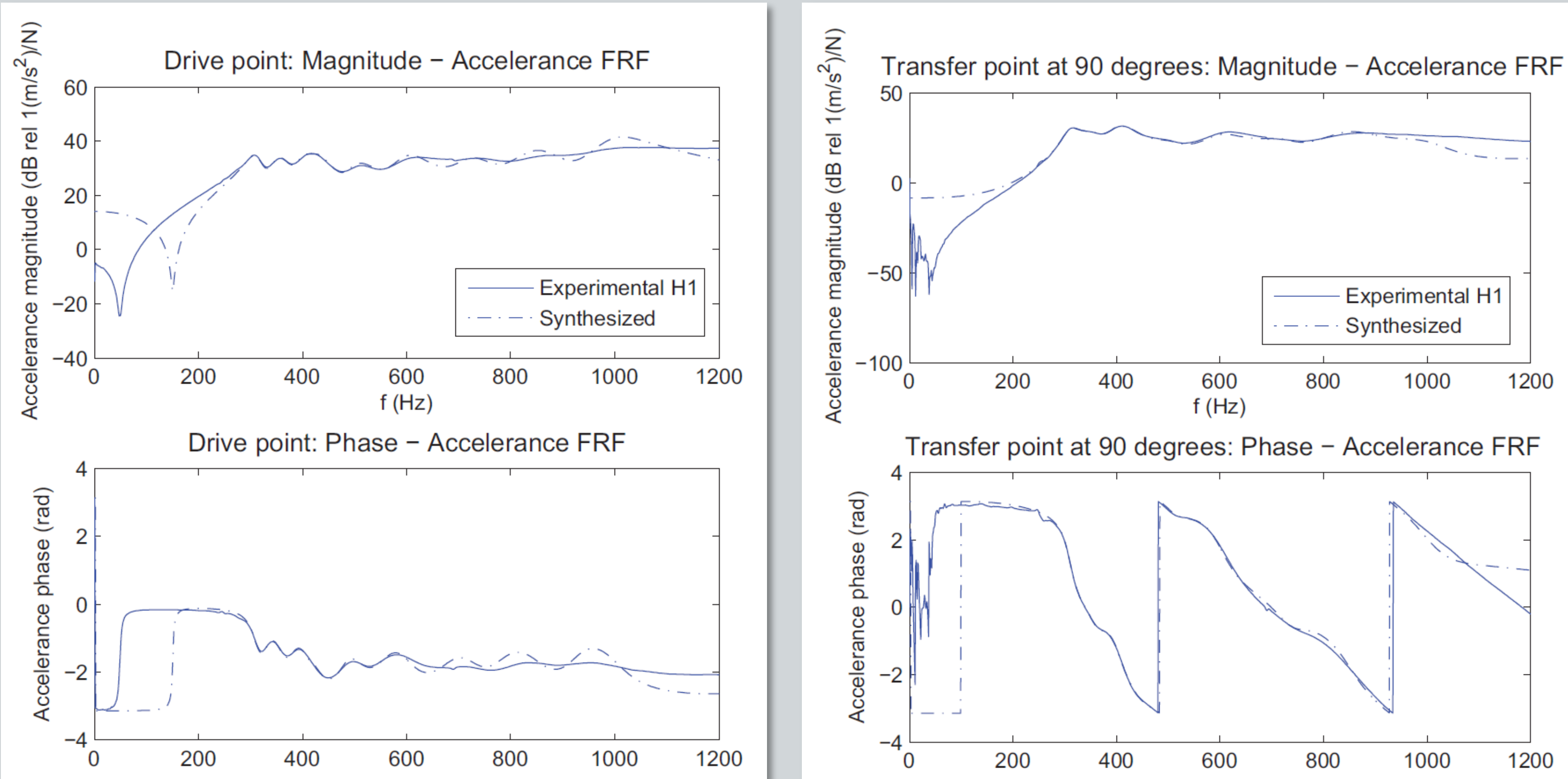
$$H(\omega) = \frac{\sum_{k=0}^{2N-1} a_k (i\omega)^k}{\sum_{k=0}^{2N} b_k (i\omega)^k}$$

- Curve-fitting performed for frequency range 280-1200 Hz to include the few visually identifiable modes

$$e_f = \sum_{k=0}^{2m-1} a_k (i\omega_f)^k - \tilde{H}(\omega_f) \sum_{k=0}^{2m} b_k (i\omega_f)^k$$

- Synthesized FRFs constructed based on extracted modes

Modal testing – Modal analyses



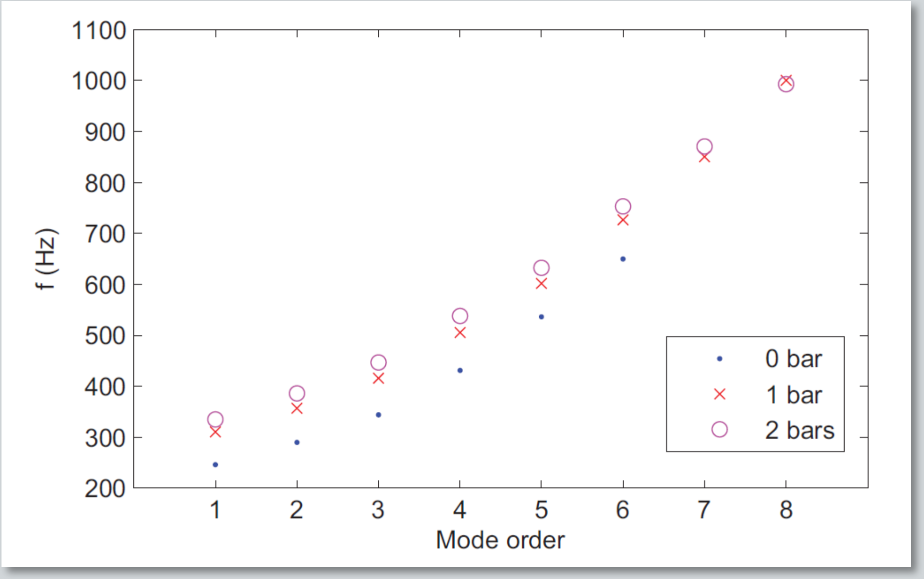
Experimental and synthesized accelerance FRFs at the drive point (left) and a transfer point (right) for the inflation pressure of 1 bar

Modal testing – Modal analyses

- Extracted modal parameters for inflation pressure of 1 bar:

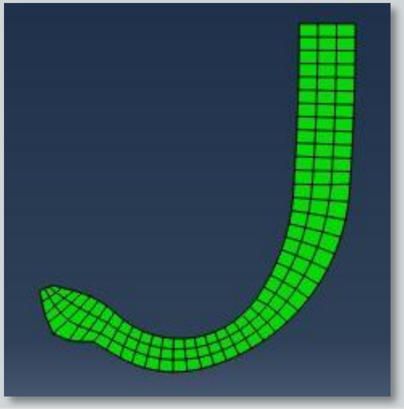
Mode	1	2	3	4	5	6	7	8
f(Hz)	310	357	416	505	602	726	850	1000
ζ(%)	4.9	5.4	4.6	6.2	5.9	5.6	5.8	5.3

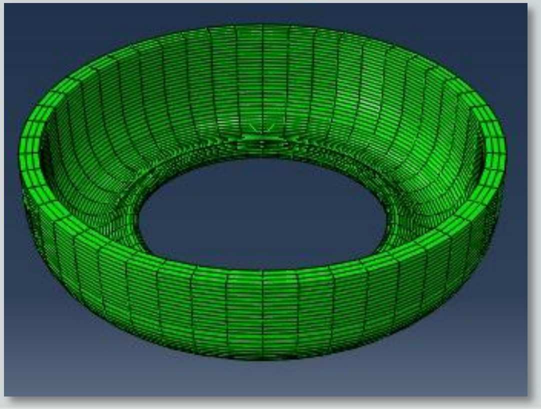
- Extracted modes for inflation pressures of 0, 1 and 2 bars:

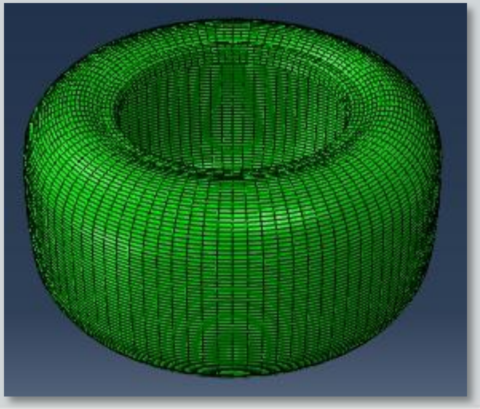


Numerical simulation – FE model-building

- Exploitation of symmetries:
  - axisymmetry about the tyre axle
  - symmetry about the median plane of the tyre
- Properties of the tyre:
  - rim considered perfectly rigid
  - rubber: elastic, homogeneous material
  - Young's modulus: 117 MPa
  - Poisson's ratio: 0.48
  - Density : 1100 kg/m^3

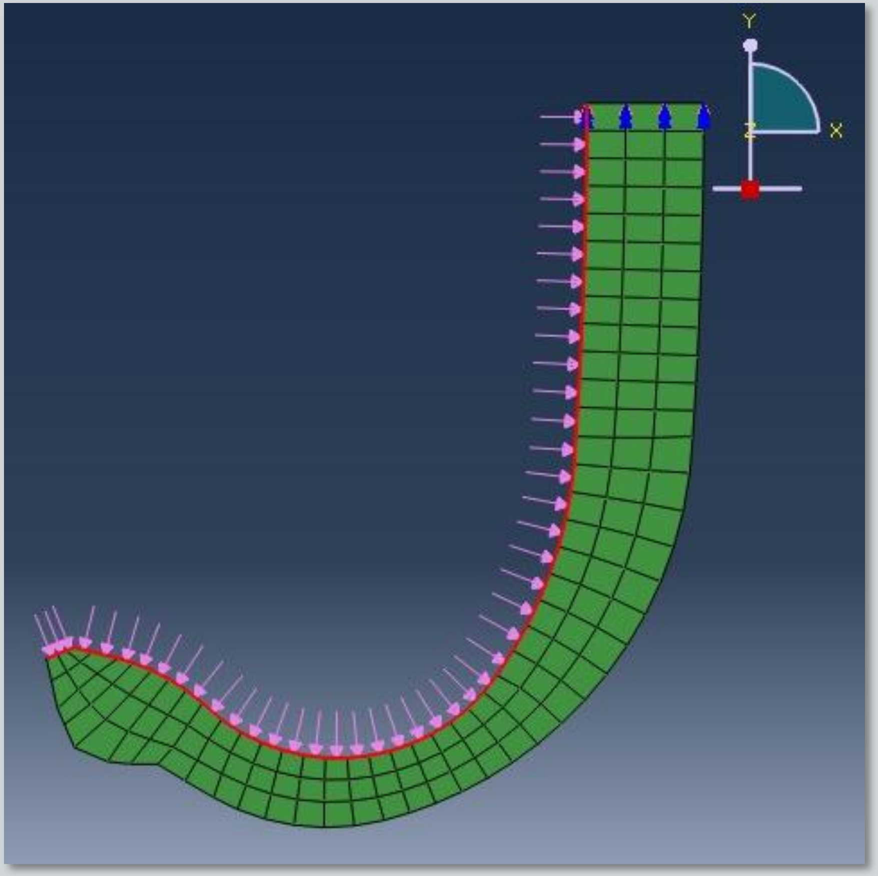


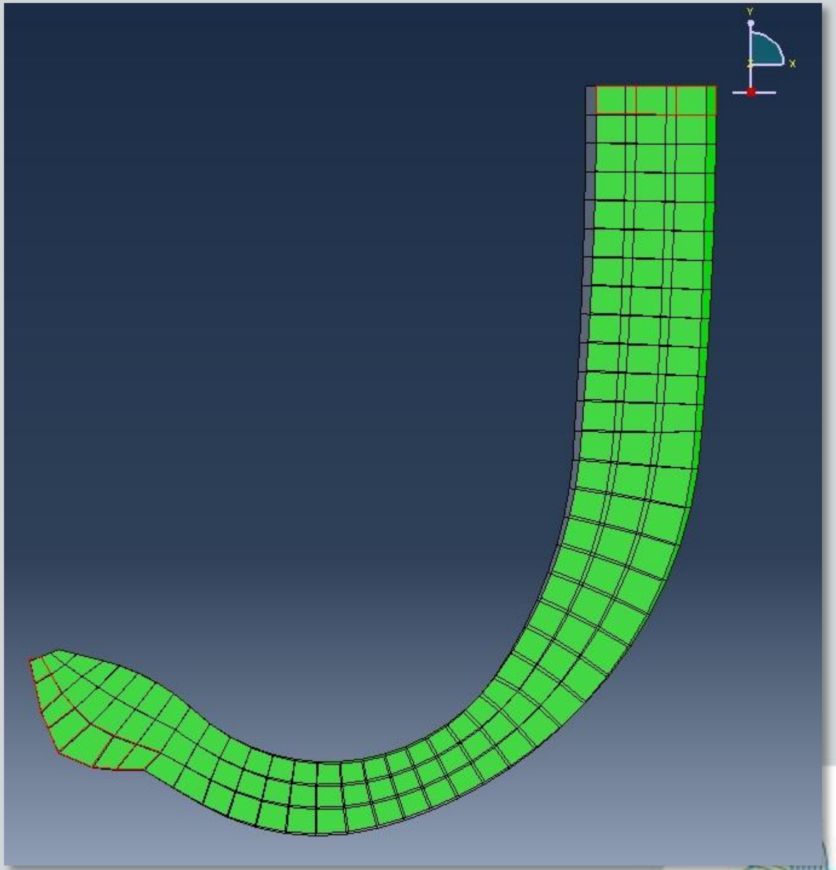




Numerical simulation – Model-building

- Pressurization of the tyre:



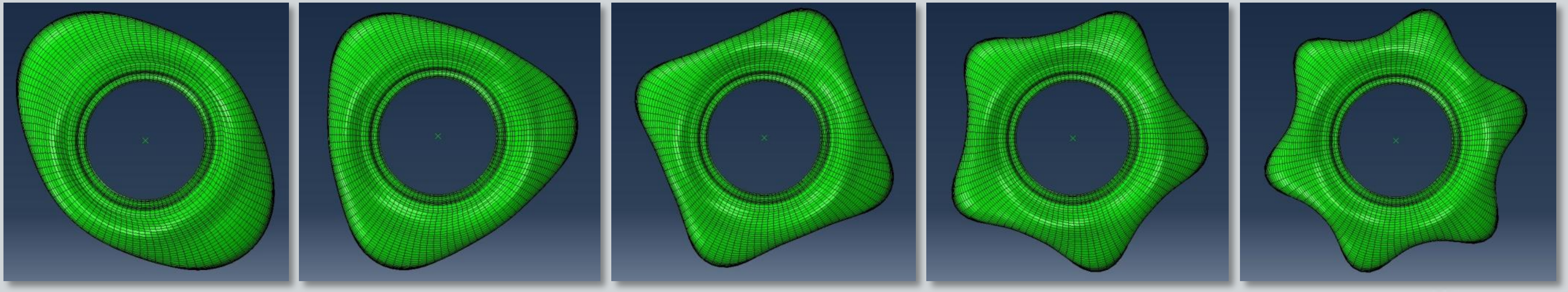


Numerical simulation – Modal analyses

- Extracted modal parameters for inflation pressure of 1 bar:

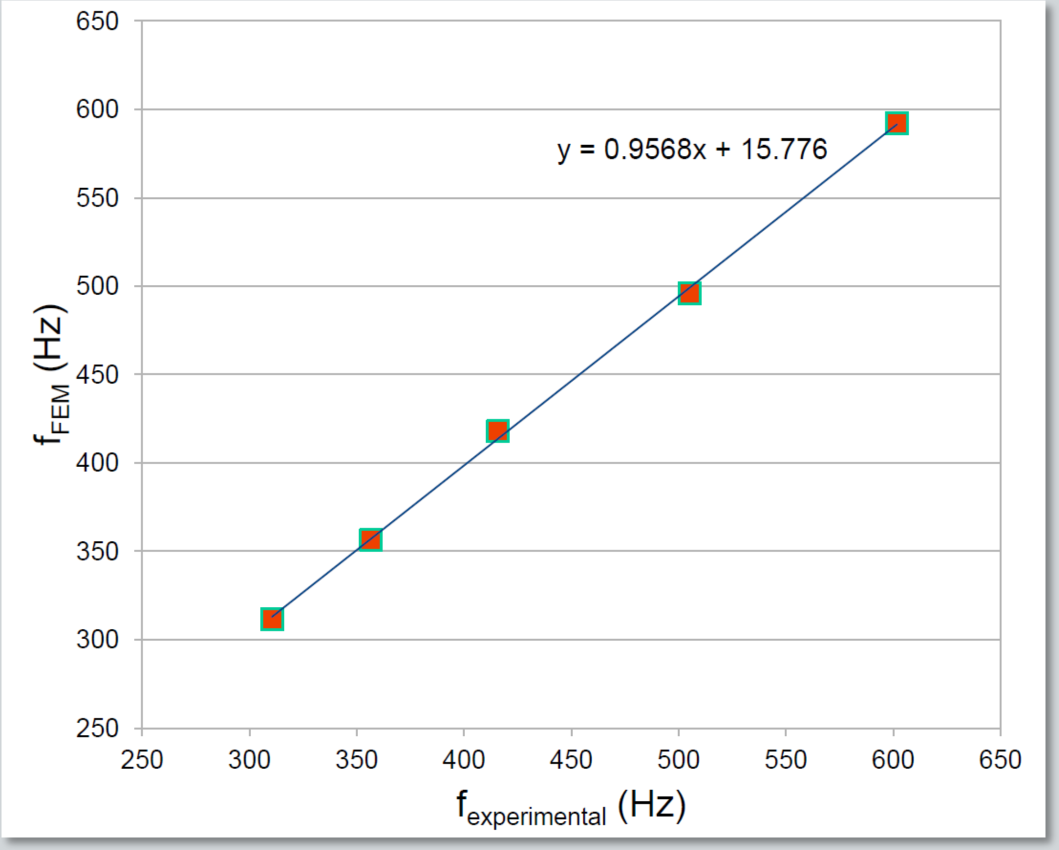
Mode	1	2	3	4	5	6	7	8
f(Hz)	310	355	419	502	605	729	871	1031

- Extracted modes for inflation pressures of 0, 1 and 2 bars:

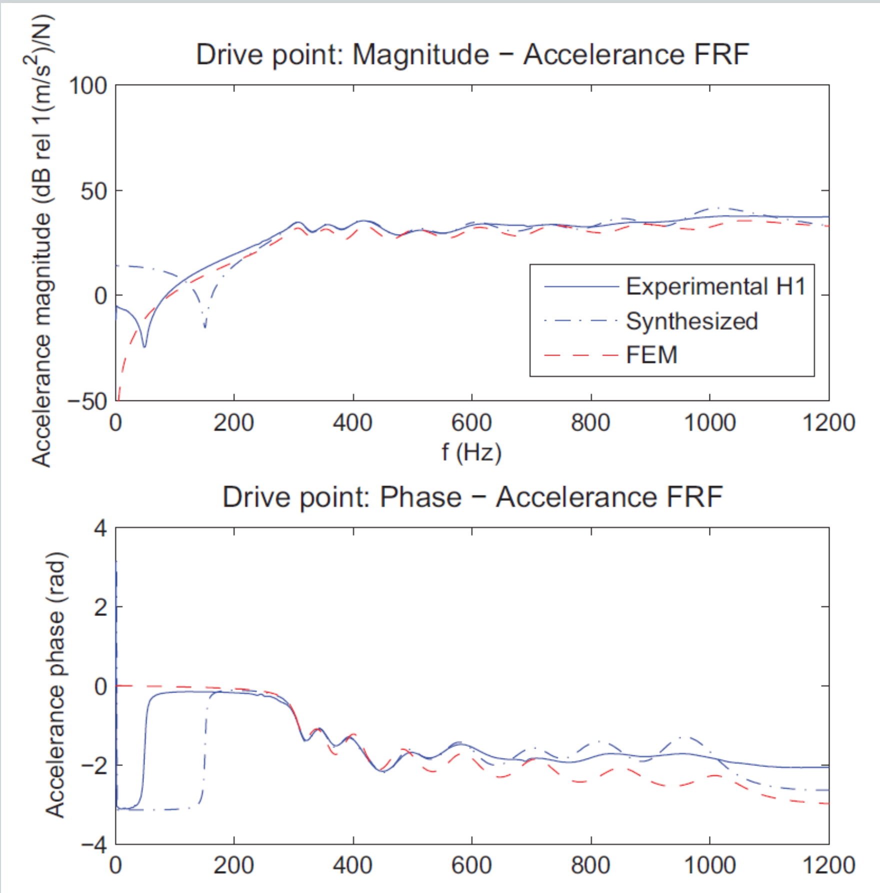


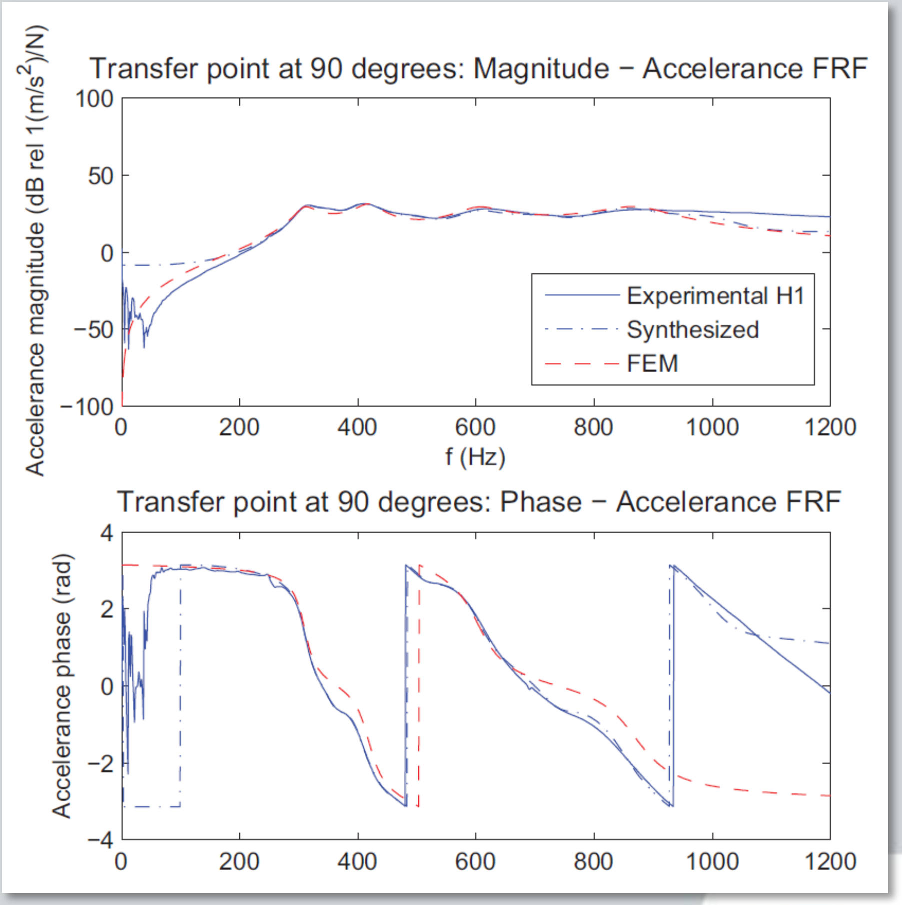
Comparison of results

- Experimental and numerical results of eigenfrequencies for inflation pressure of 1 bar:



Comparison of results





Experimental, synthesized and numerical accelerance FRFs at the drive point (left) and a transfer point (right) for the inflation pressure of 1 bar

Conclusions and perspective

- Experimental modal analyses on a go-kart tyre for inflation pressures of 0, 1 and 2 bars
- Finite element tyre model having good agreement in terms of modal properties with experimentation for 280-800 Hz
- Investigation of the rolling contact problem using this tyre model

Thank you for your attention!

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