Axis 1: Interaction between vehicle and infrastructure

A dynamic multi-asperity contact model for tyre/road noise

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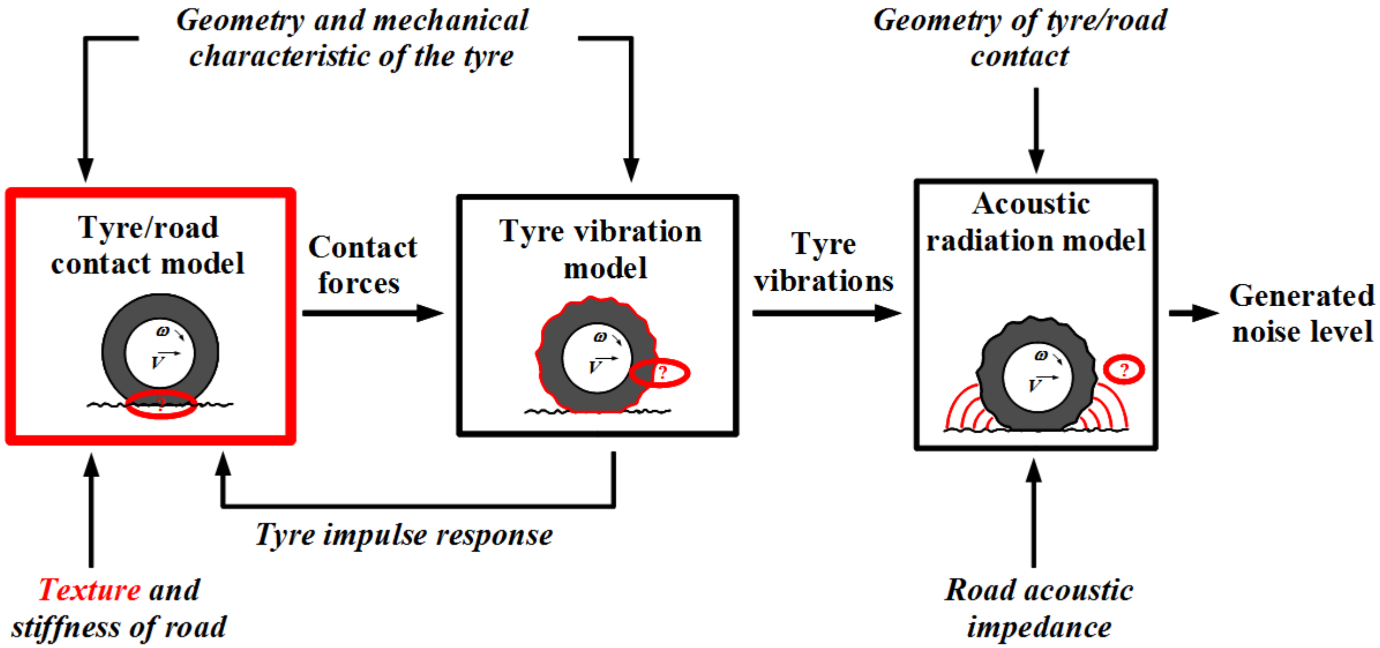
- A multi-asperity tyre/road contact model
- Results on a small sample of road surface
- Tyre/road contact forces on real road surfaces
- Conclusions

❑ Tyre/road contact noise



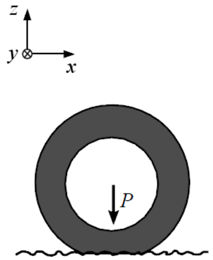
- Texture influence on dynamic contact forces and on tyre/road noise ?

- 2 possible approaches
  - Finite dimension of the problem: FEM, BEM
  - ***Elastic solid can be considered as a half-space around the contact area***

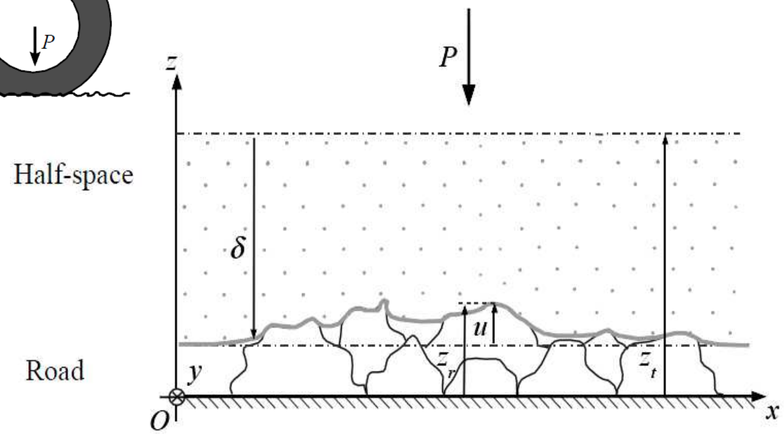
- Hypotheses of the developed model:
  - Tyre tread:
    - 3D elastic half-space
  - Road surface:
    - perfectly rigid asperities
  - Small strain
  - No friction
  - No dynamic of the half-space

❑ Contact problem

➢ Boussinesq's potential theory



$$\forall M \in \Sigma,\ u(M) = \int_{\Sigma} T(M,S)p(S)d\Sigma$$



➢ Signorini's contact conditions

$$\forall M \in \Sigma_c,\ u(M) = z_r(M) - \delta - z_t(M) \qquad p(M) > 0$$

$$\forall M \in \bar{\Sigma}_c,\ u(M) > z_r(M) - \delta - z_t(M) \qquad p(M) = 0$$

➢ Equilibrium condition

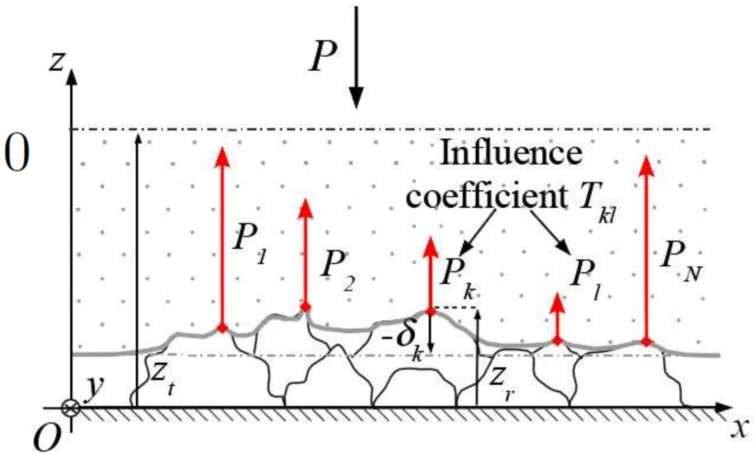
$$-P = \int_{\Sigma} p(S)d\Sigma$$

- Partitioning of the road surface

$$\forall l \in [1, N],\ \Sigma = \bigcup_{l=1}^{N} \Sigma_l$$

- Contact law for the asperity k

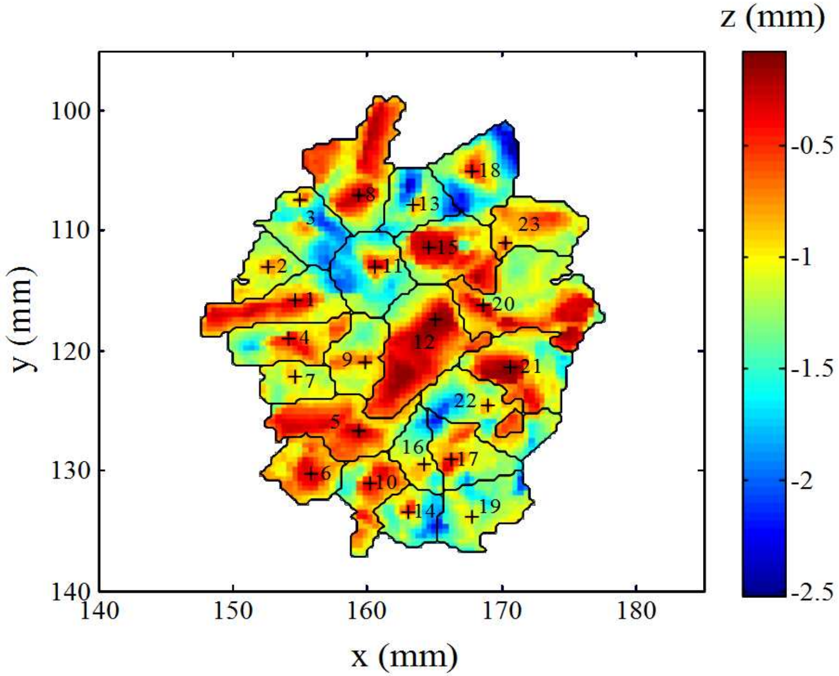
$$P_k = \begin{cases} f_k(\delta_k) & \text{if } \delta_k > 0 \\ 0 & \text{if } \delta_k \leq 0 \end{cases} \quad \text{and } P + \sum_{k=1}^{N} P_k = 0$$



$$\delta_k = z^s_{r,k} - \delta - z^s_{t,k} - \sum_{\substack{l=1 \\ l \neq k}}^{N} T_{kl} P_l$$

- Resolution by Newton-Raphson algorithm

A portion of about 7 cm² of a Dense Asphalt Concrete 0/10



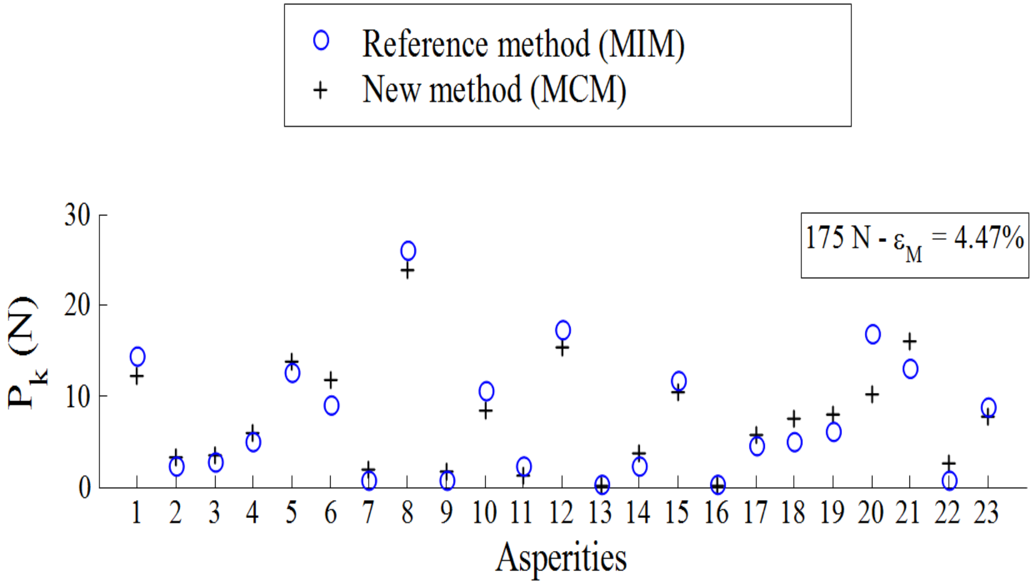
MCM Vs **MIM**

- Young modulus: 2.5 MPa
- Poisson coefficient: 0.5
- No curvature of the tyre
- 23 asperities for **MCM**
- 4400 square elements for the **MIM**
- Loading: from 0 to 175 N

  in 280 load steps for **MCM**

  in 15 load steps for **MIM**

Results on a small sample of road surface



$$\varepsilon_M = 100 \frac{\sum_{k=1}^{N} |P_k - P_{k_{ref}}|^2}{\sum_{k=1}^{N} |P_{k_{ref}}|^2} \qquad \varepsilon_M < 5\%$$

- MIM:

15 load steps → pressure distribution in 1h15min

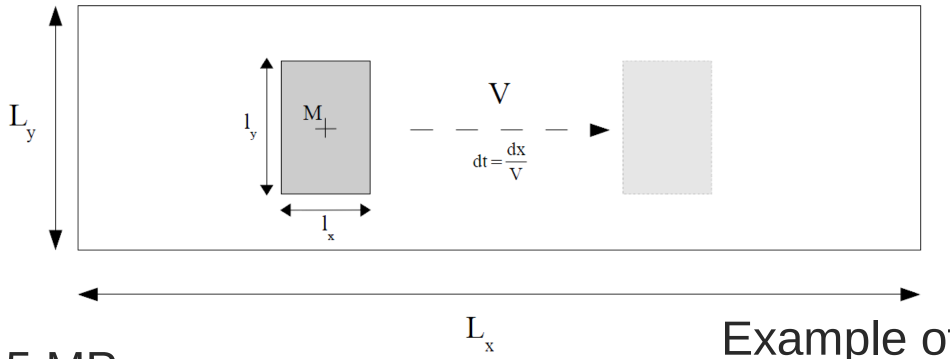
- MCM:

280 load steps → contact force distribution in 1s

MCM seems good enough to predict tyre/road noise at low-frequency (f < 1000 Hz)

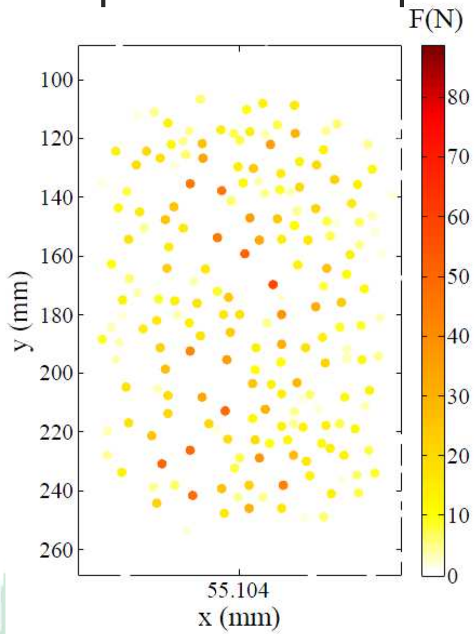
Calculation data

Rectangular area of interest

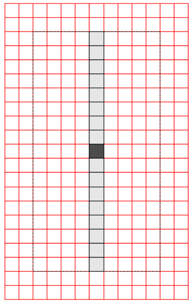


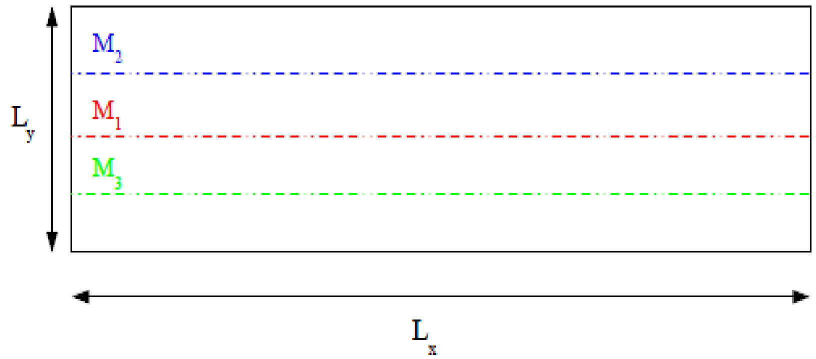
- Young modulus: 2.5 MPa
- Poisson coefficient: 0.5
- Slick Tyre with curvature
- ~12000 asperities
- Loading: loading phase from 0 to 3000 N and then 3000 N for all steps

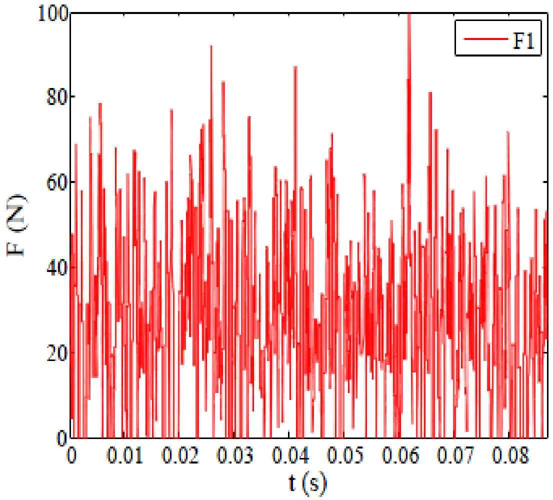
Example of contact print

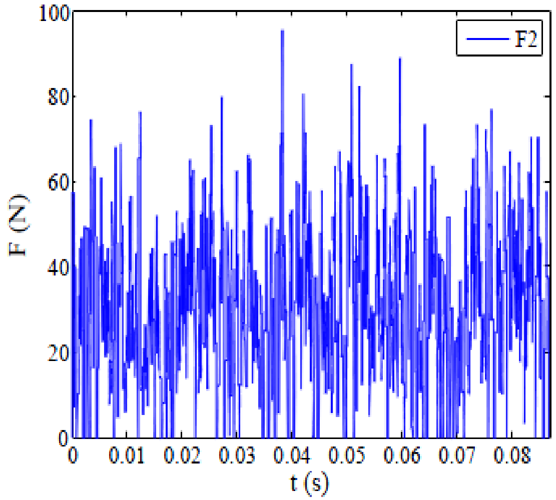


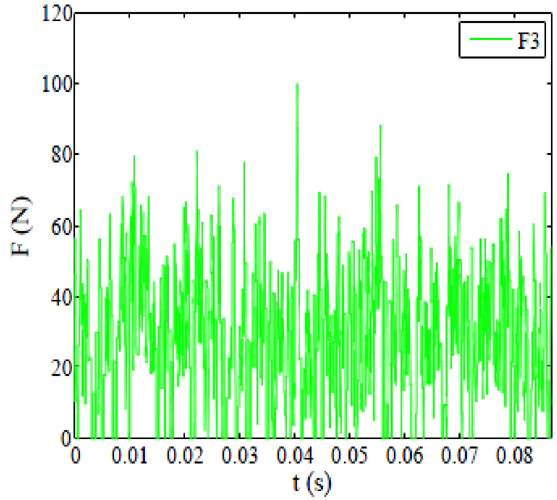
Example of three temporal results at **three different positions** on the same sample of road surface



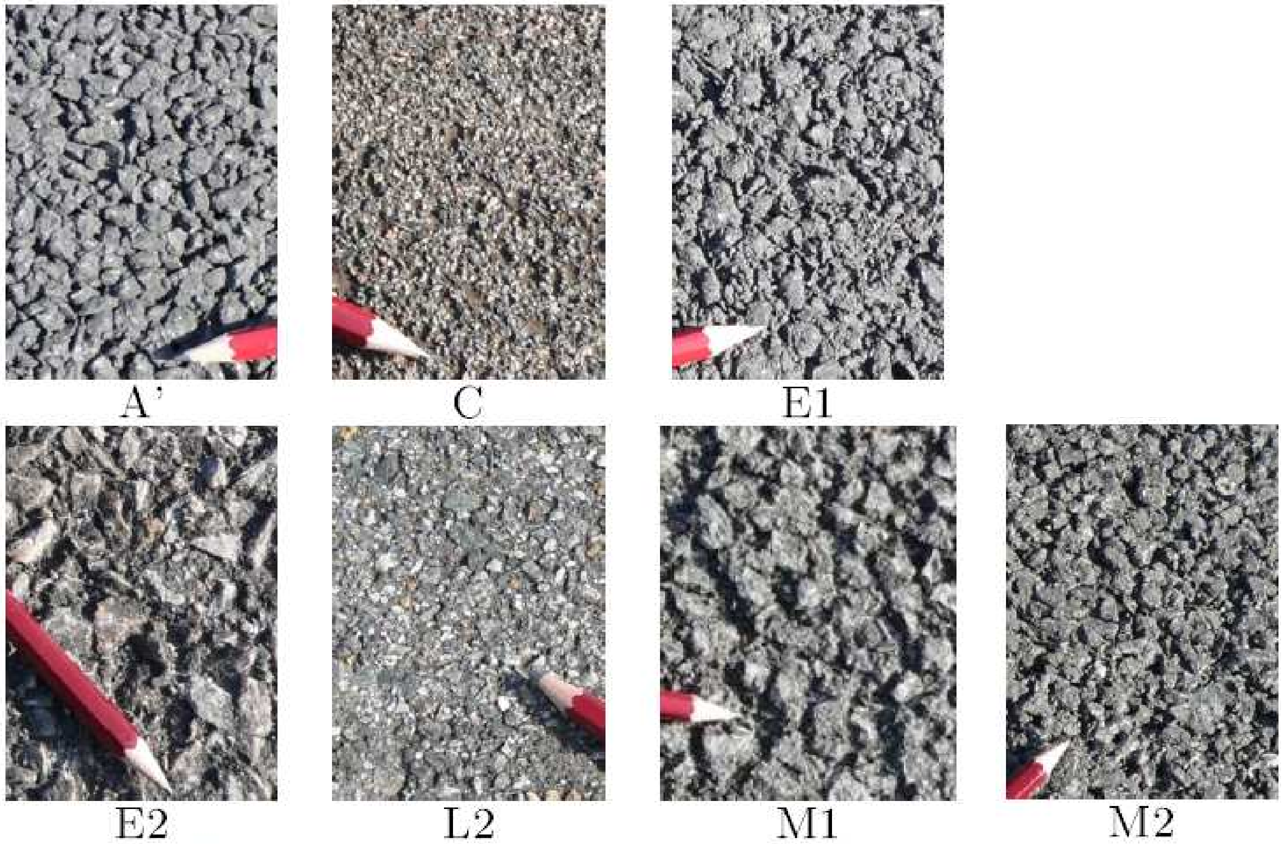






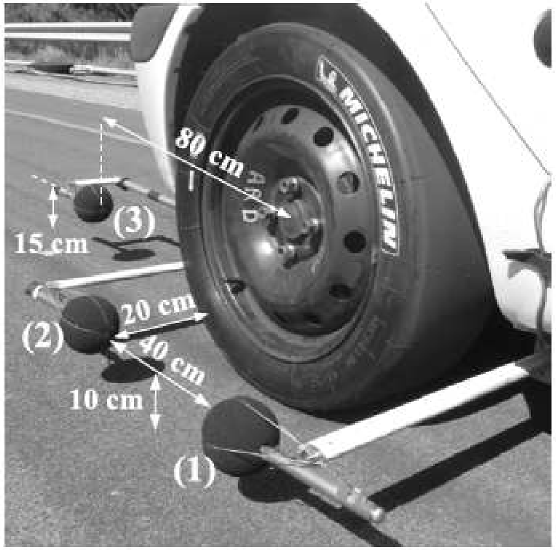


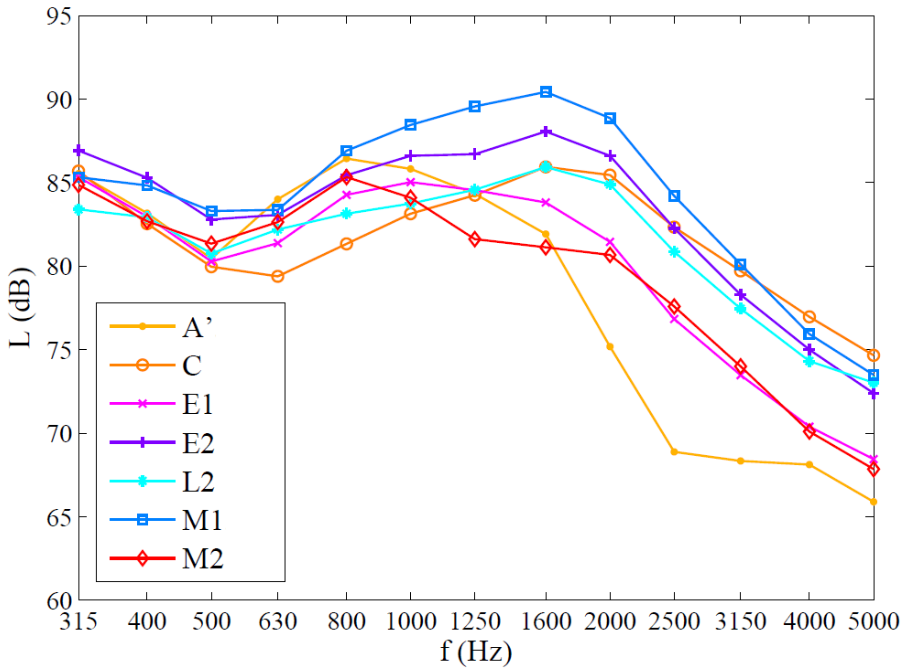
Correlation between contact force and noise levels



Seven road surfaces of the test track of IFSTTAR (Nantes, France)

CPX noise measures with a slick tyre (Michelin Racer Slick, 186/57R/15)





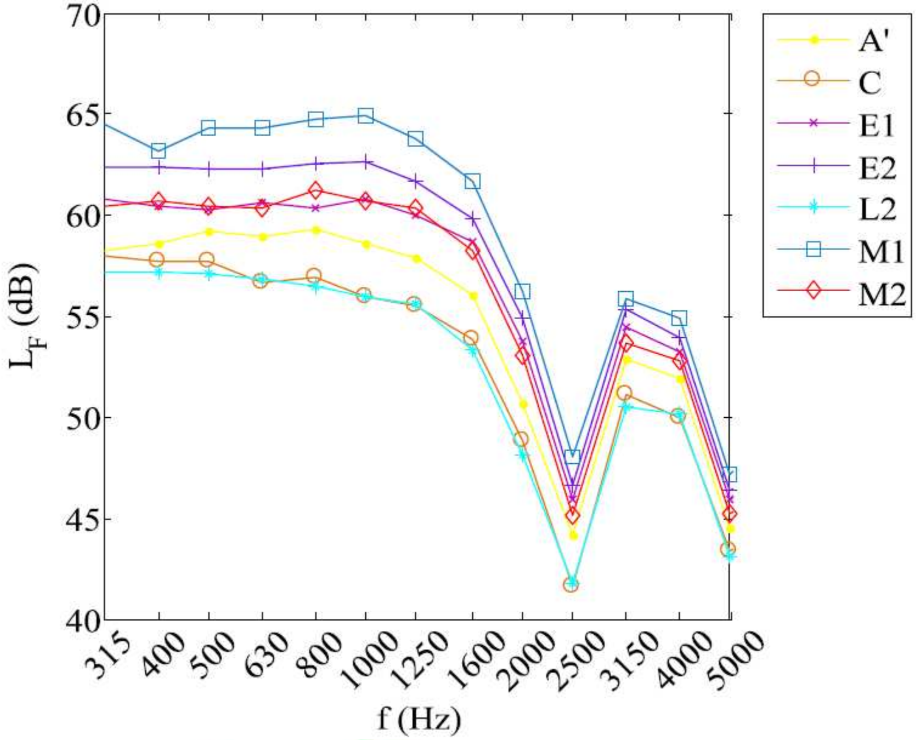
Recomposed noise level (dB) between 315 and 1000 Hz at V_{ref} = 90 km/h

	A'	C	E1	E2	L2	M1	M2
L_r	92.5	90.4	91.4	93.1	90.7	93.6	91.5

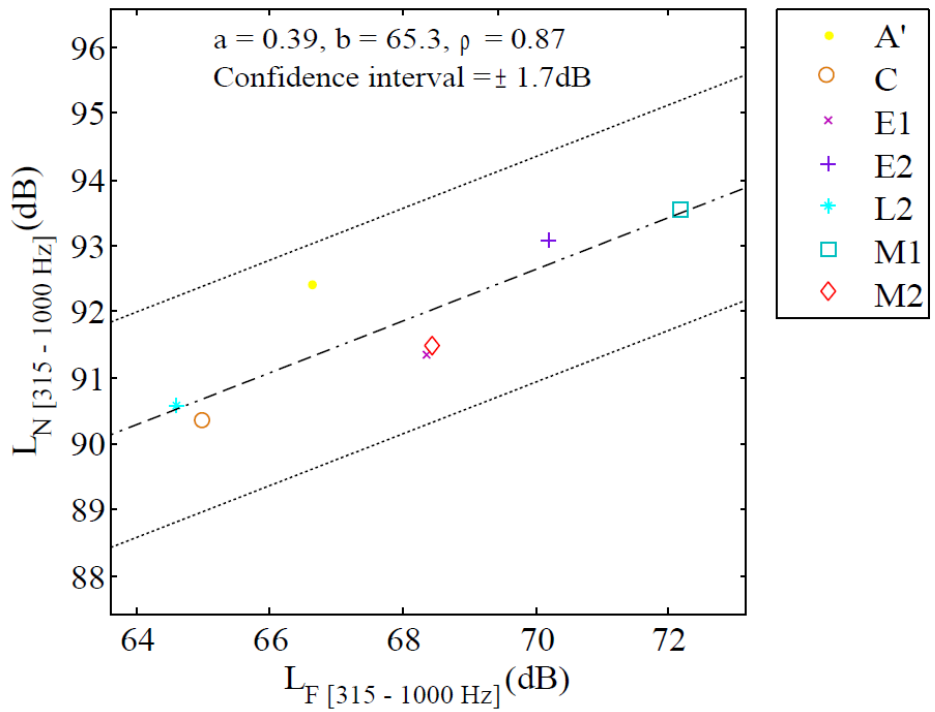
Tyre/road contact forces on real road surfaces

Correlation between contact force and noise levels

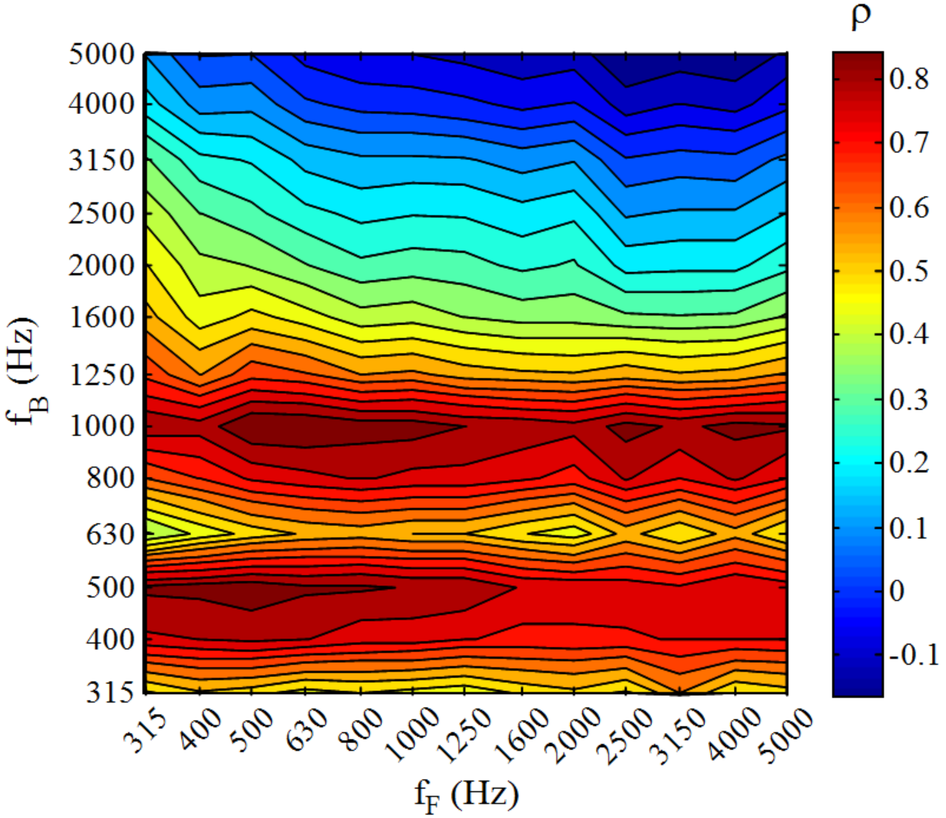
Contact force spectra calculated for the seven road surfaces at 90 km/h



Correlation between **recomposed noise levels** and **recomposed contact force levels** from 315 to 1000 Hz



Iso-correlation curves between **noise levels** and **contact force levels** at 90 km/h



Conclusions:

- Validation of MCM on real road surface
- Calculation of dynamic contact forces for a slick tyre on real road surfaces
- Good correlation between calculated contact force levels and measured noise levels from 315 to 1000 Hz

Future work:

- Calculation of dynamic contact forces for a patterned standard tyre with the introduction of tyre vibration
- Confirmation of the correlation between calculated contact force and noise levels

Thanks for your attention