Cerema

IFSTTAR

Multi-physical model for tire/road contact – the effect of surface texture

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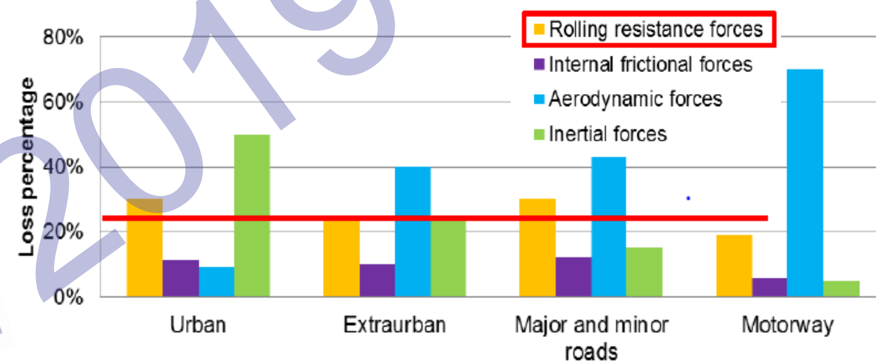
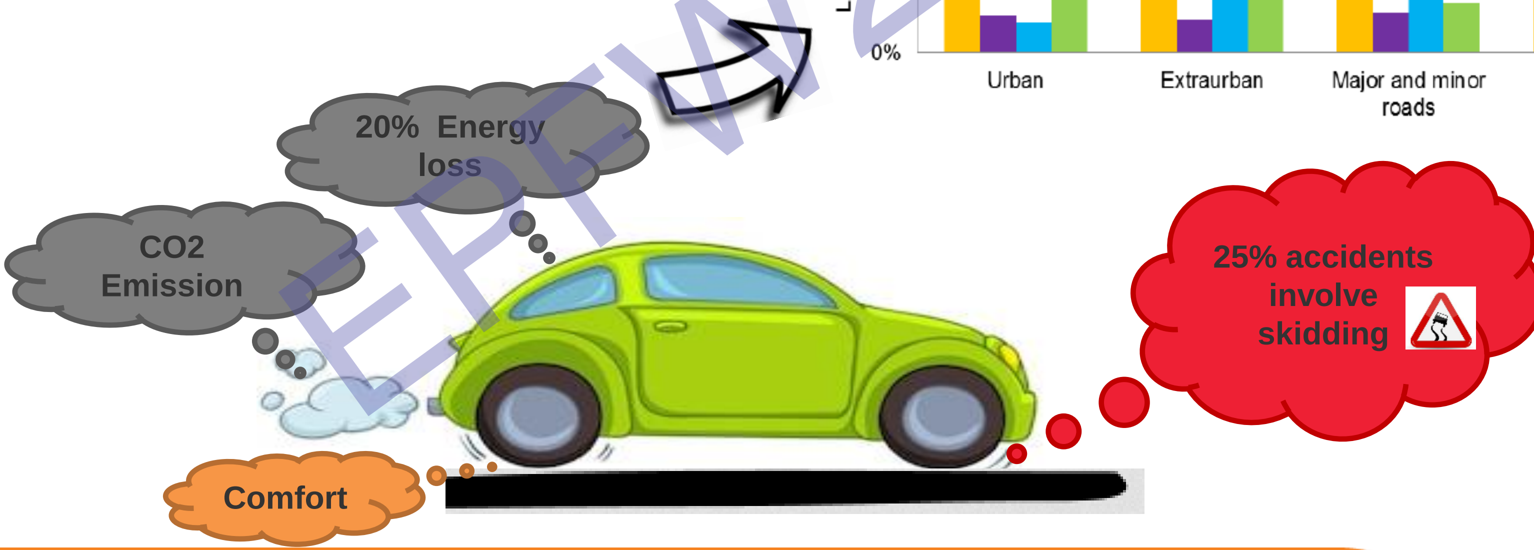
Introduction

- Main Issues related to tire-road interaction
  - Safety
  - Emission and fuel consumption
  - Comfort

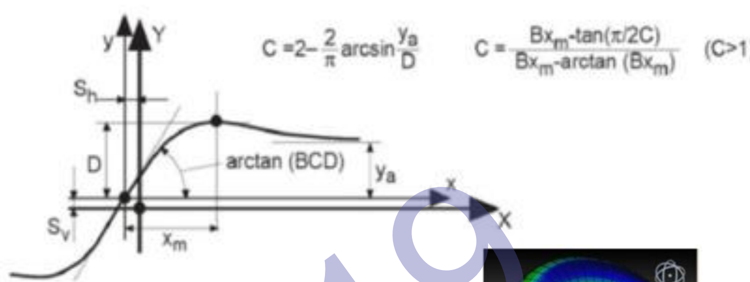
Vehicle energy usage

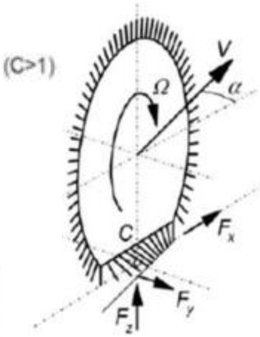


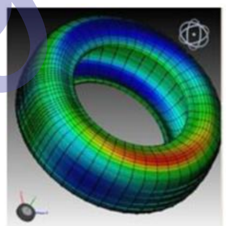


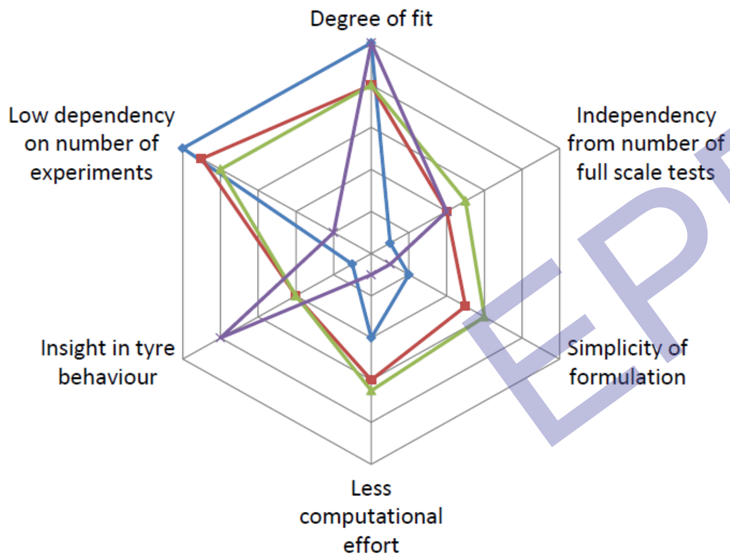
State of art

- Tire models
  - Empirical models
  - Semi-empirical model
  - Complex physical model(FEA)
  - Physical model
    - Friction models [J Svendenius]
    - Rolling resistance [M Davari]

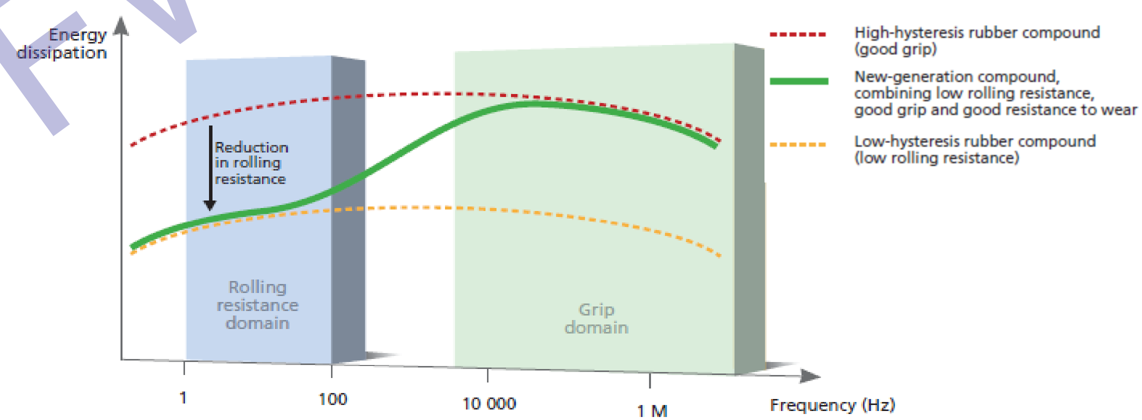








Trade off between grip and rolling resistance



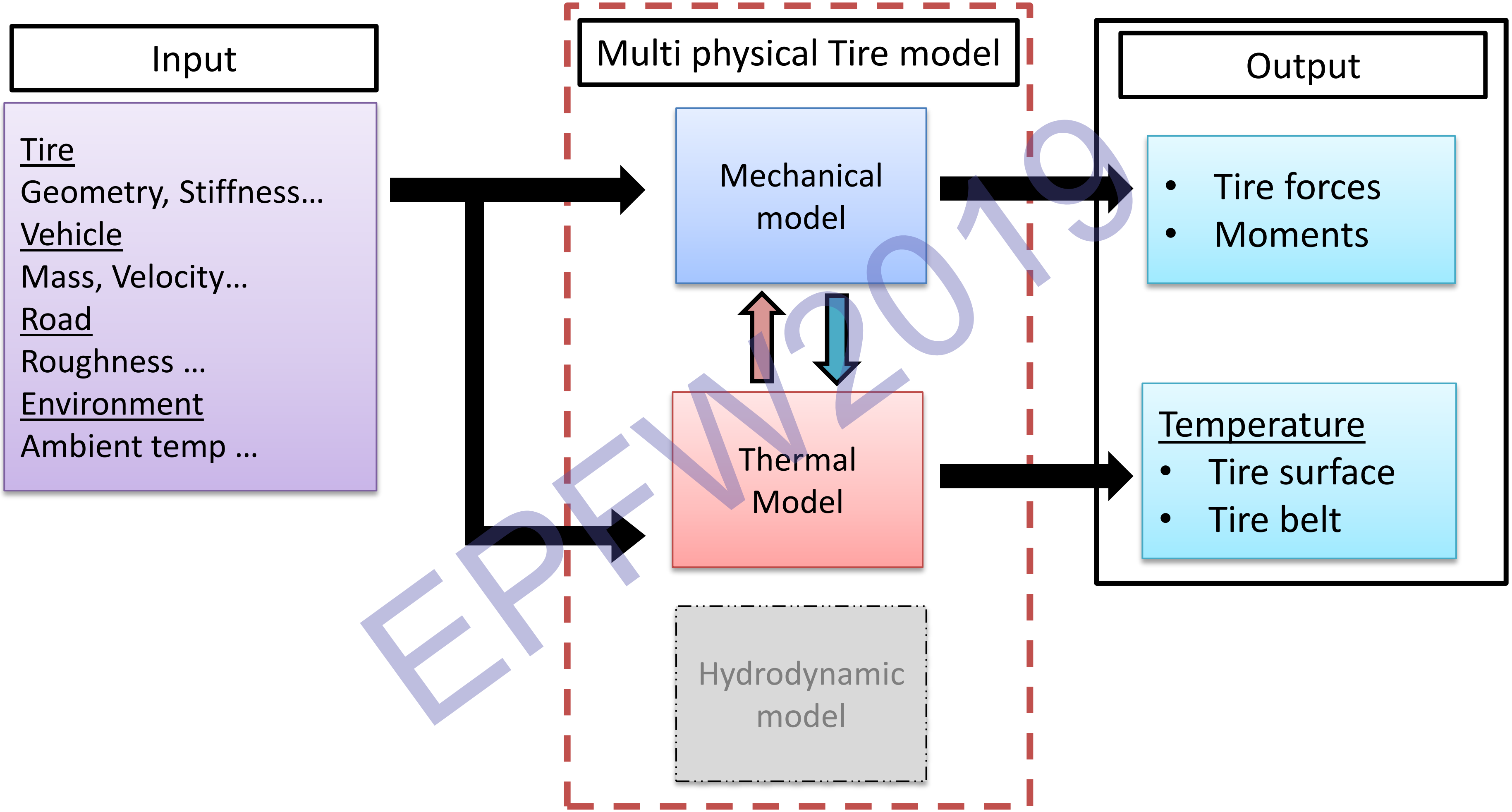
Source Michelin

Research objective

Develop a tire-road interaction model which can take account the impact of parameters effecting friction and rolling resistance to provide precise contact forces

Road properties, stiffness, speed as mechanical parameters
Temperature as thermal parameters
Water height as hydrodynamic parameters

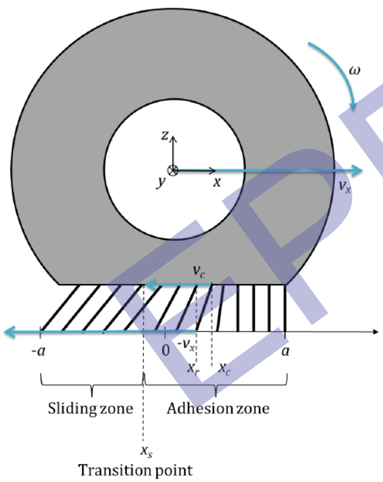
Flow chart of model

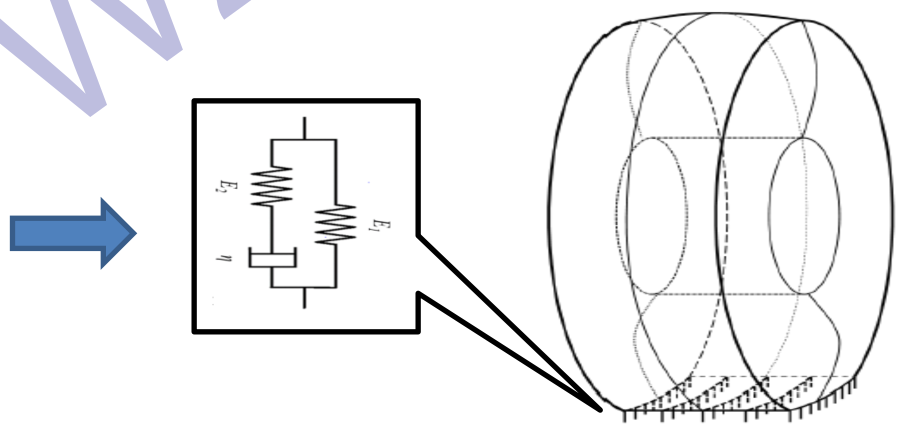


New multi physical tire model

- Mechanical model
  - Extension of classical brush model
  - Tread is modeled with finite number of bristles in contact
    - Maxwell 3 parameter model is used
    - Forces calculated with deformation of these parameters

$$F_{M}^{t} = F_{M}^{ve} = \sum f_{bristles}^{ve}(M = x, y, z)$$





* Pacejka, H,2002
** Davari M, 2015

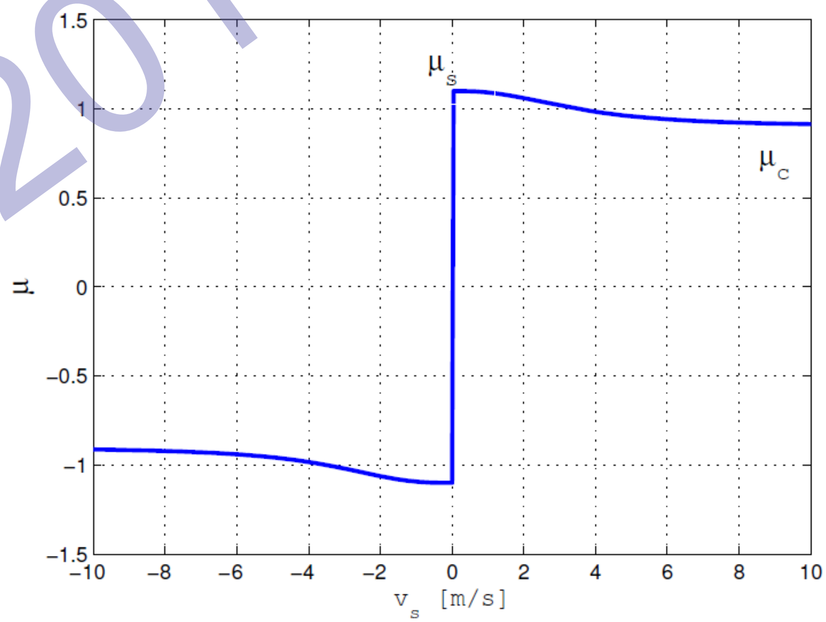
New multi physical tire model

- Control
  - Deflection ≤ 0 : Bristle not in contact
  - Fz ≤ 0 : Bristle not in contact

- Dynamic friction model

$$\mu_x(v_{slid,x}) = \mu_{c,x} + \frac{\mu_{s,x} - \mu_{c,x}}{1 + |v_{slid,x}/v_{str,x}|^{2.5}}$$

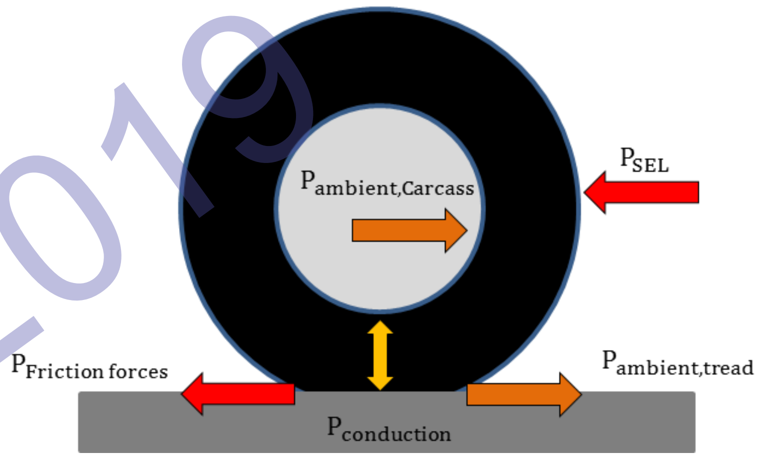
$$\mu_y(v_{slid,y}) = \mu_{c,y} + \frac{\mu_{s,y} - \mu_{c,y}}{1 + |v_{slid,y}/v_{str,y}|^{2.5}}$$



- Sliding forces
  - Calculated using SPM

New multi physical tire model

- Thermal model
  - Heat Generation
    - Due to tire/road tangential interaction and tire cyclic deformation during rolling
  - Heat Exchange
    - With the external environment due t thermal conduction between the tread and the road , convections of the surface and the inner liner layers respectively
  - Heat conduction
    - Between the tire layer due to the temperature gradients



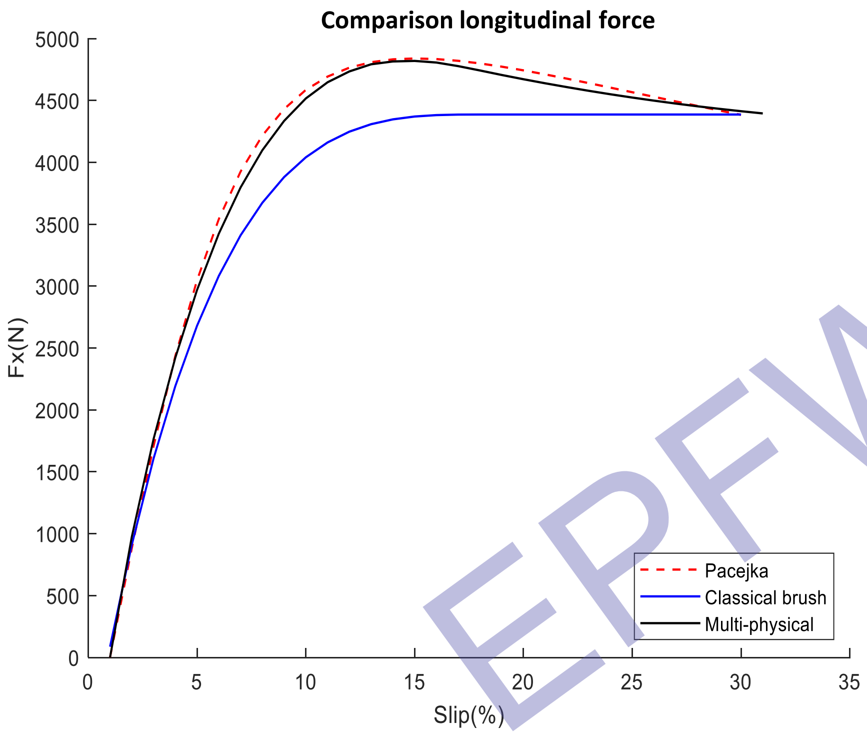
$$m_c c_v \frac{dT_{carcass}}{dt} = P_{SEL,c} + k_c(T_{tread} - T_{carcass}) * s_t + P_{ambient,carcass}$$

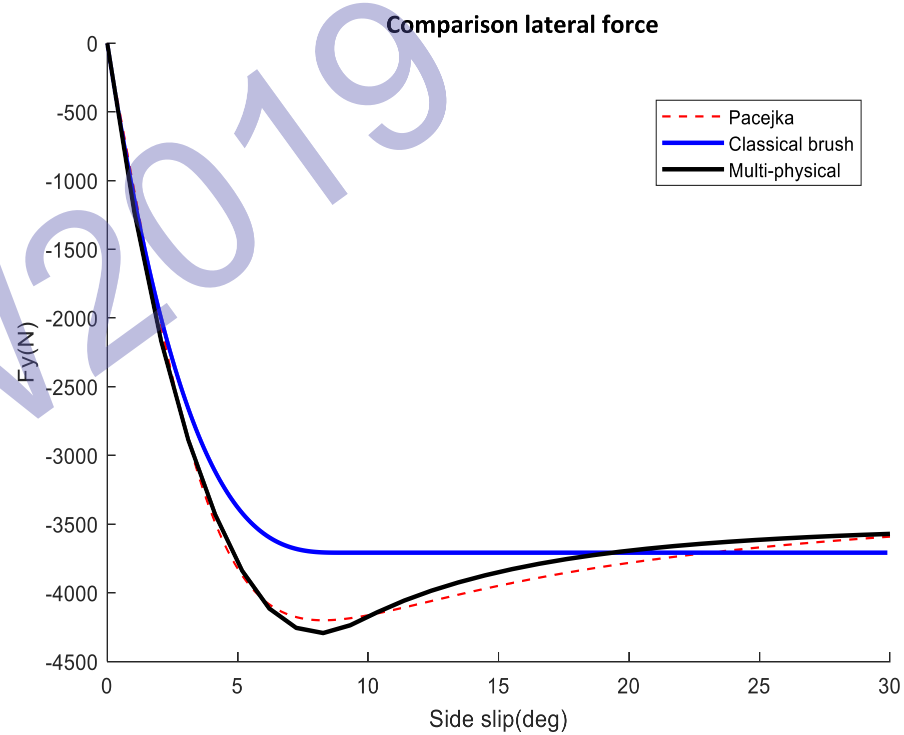
$$m_t c_t \frac{dT_{tread}}{dt} = P_{SEL,t} + P_{Friction\ forces} + P_{conduction} + P_{ambient,tread}$$

*P=Power flux

Simulation results(1/3)

- Comparison with classical brush model

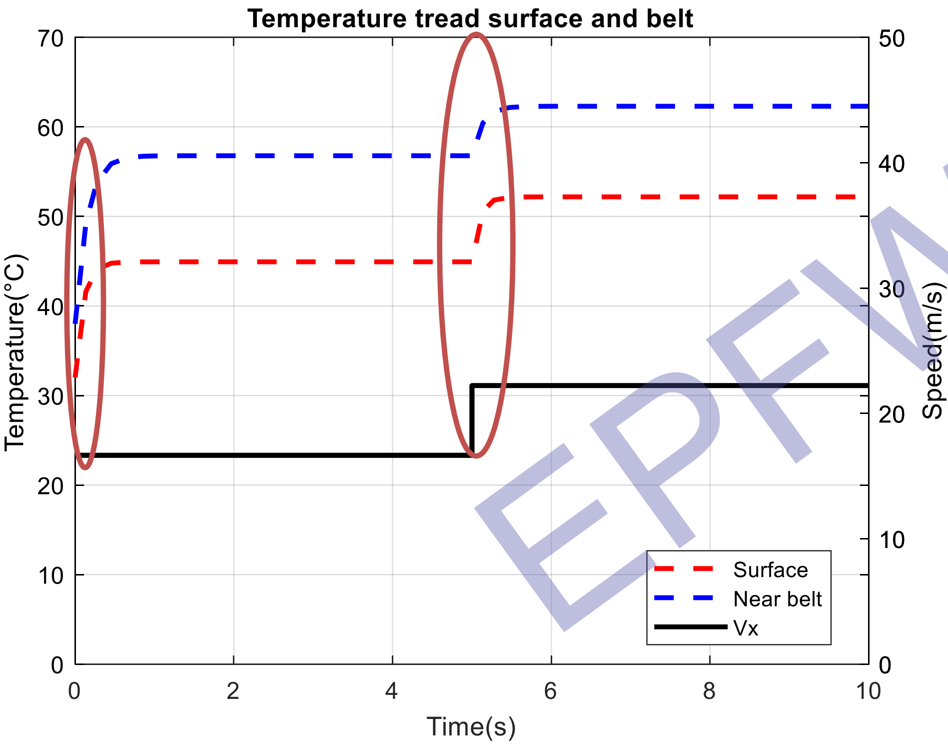




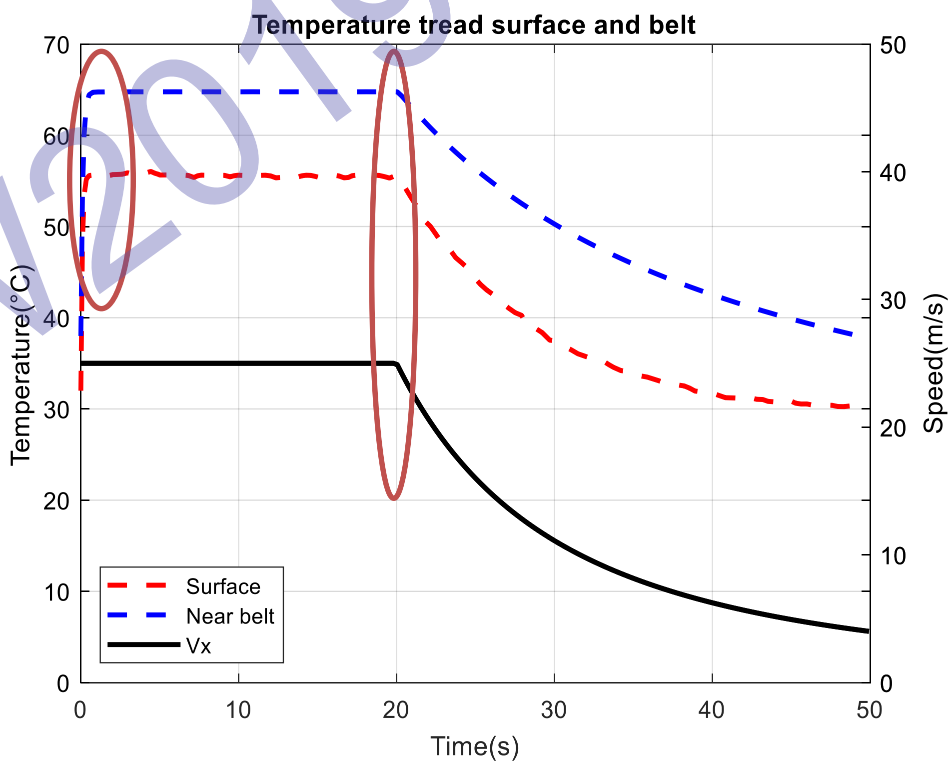
Simulation results(2/3)

- Example : temperature evolution as a function of speed

Increase in speed(Heating)

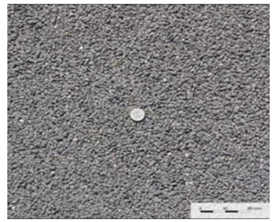
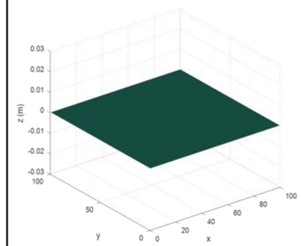
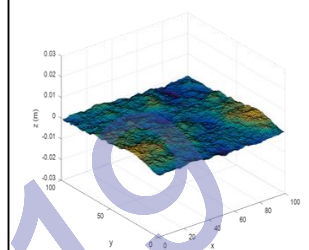
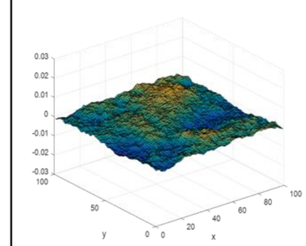
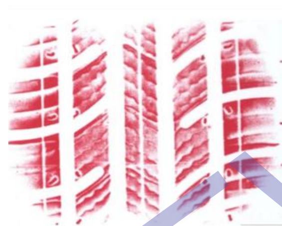
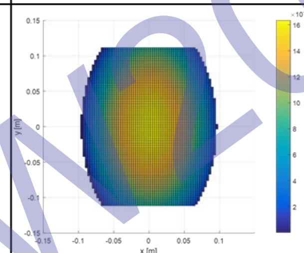
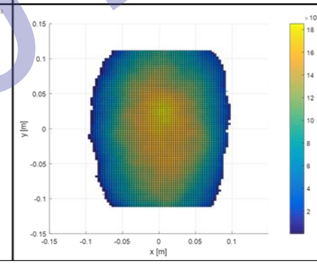
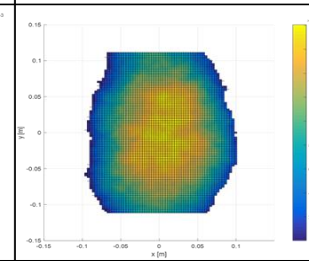


Free rolling (Cooling)

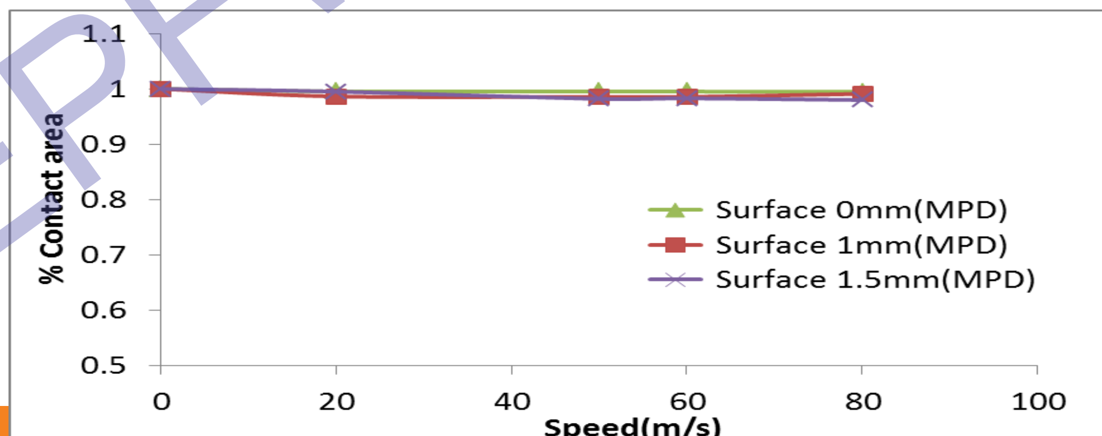


Simulation results(3/3)

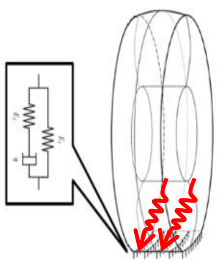
- Contact area as a function of macro texture
  (Fz = 4kN, Vx = 60Km/h)

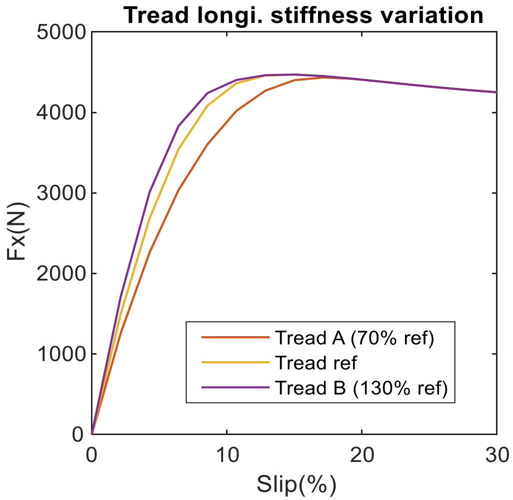
Macro roughness	0mm (MPD)	1mm (MPD)	1.5mm (MPD)
			
Contact area	100% bristles in contact	~99.2% bristles in contact	~98.6% bristles in contact
			

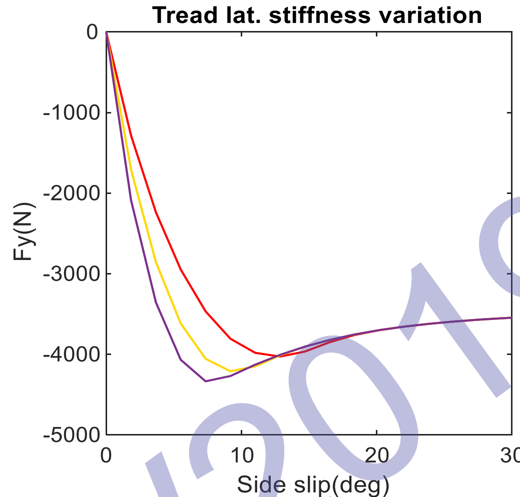
- Evolution of the contact area as a function of speed

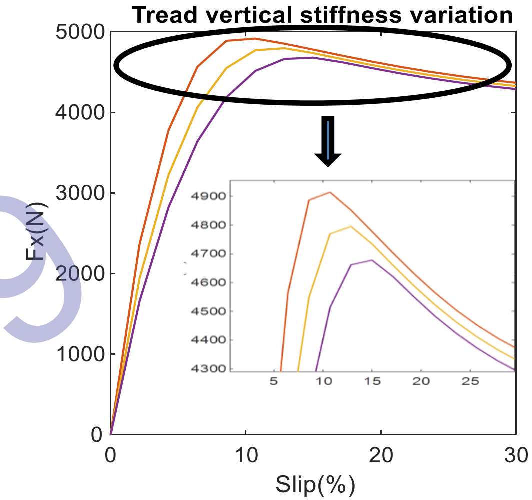


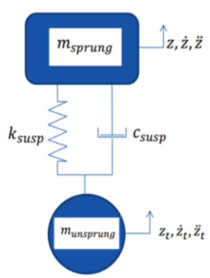
Sensitivity study(1/2)

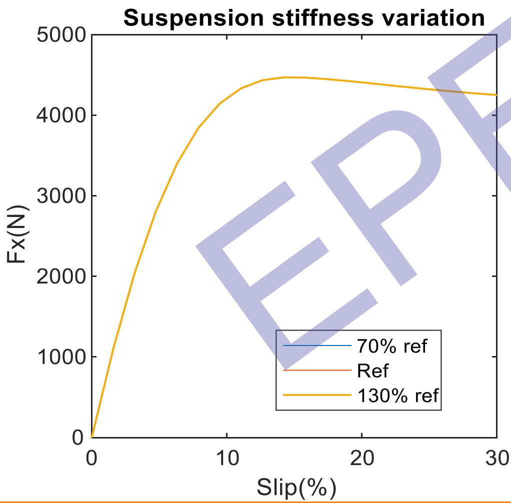


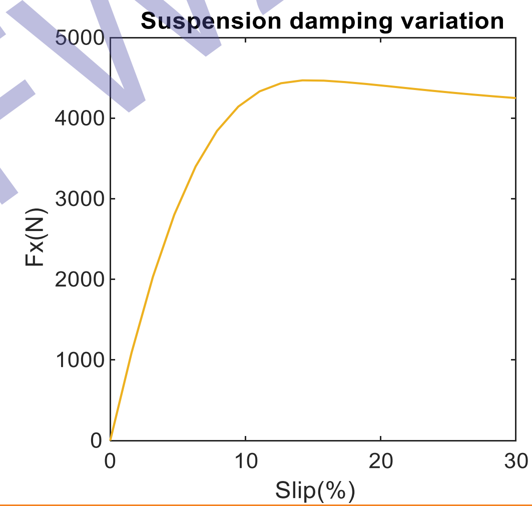


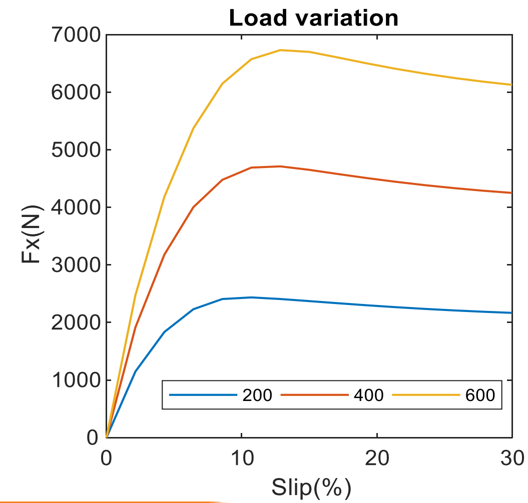




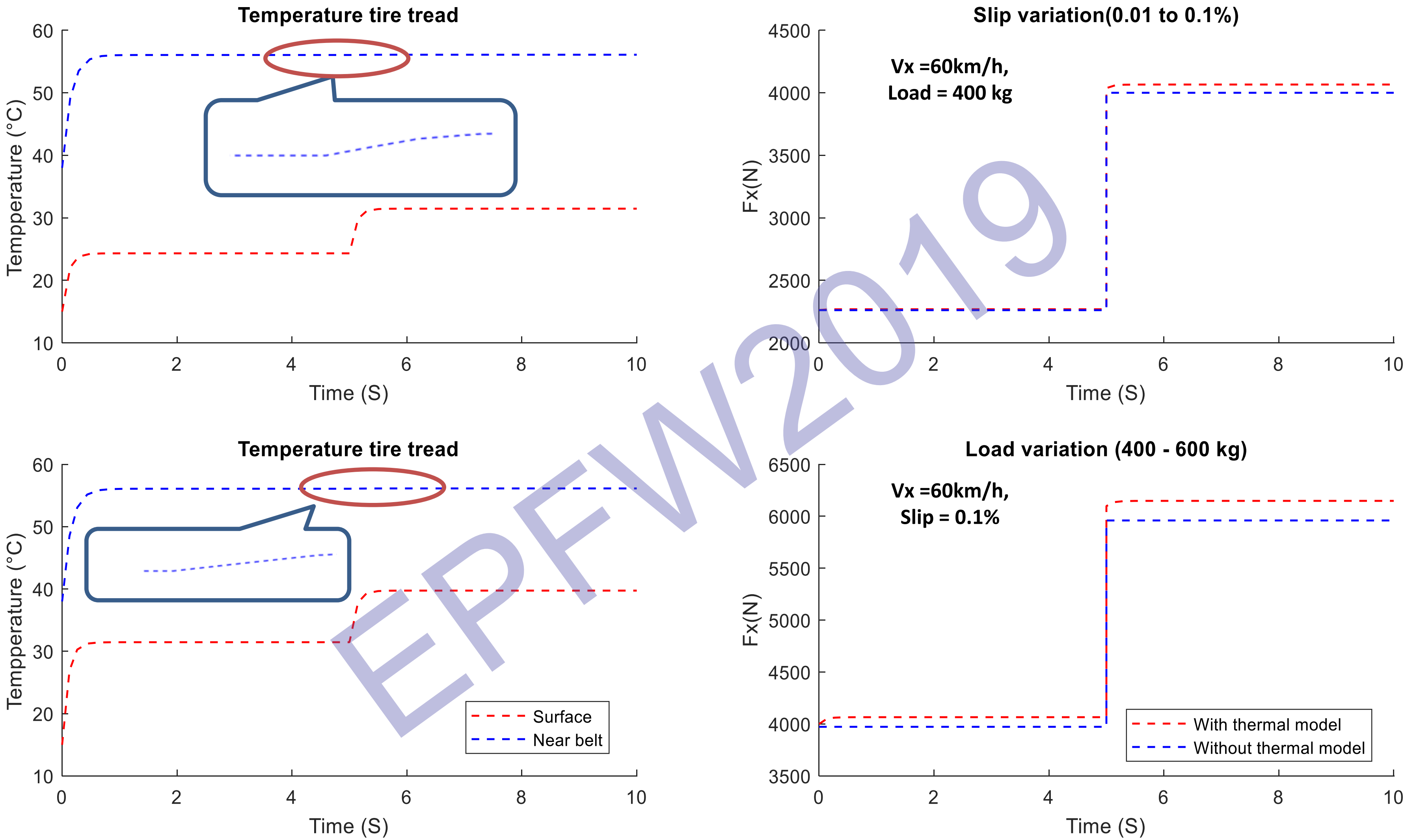




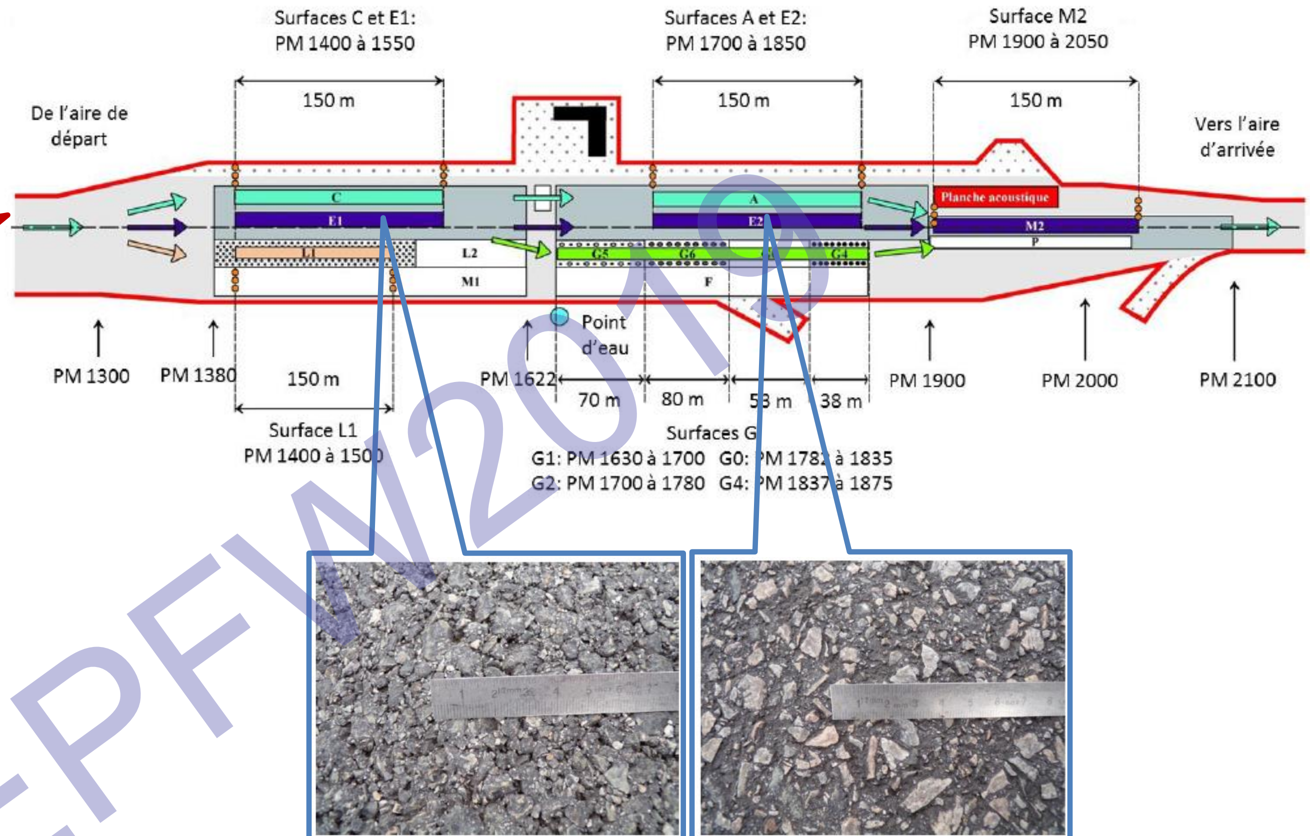




Sensitivity study(2/2)



Experimental design



E1: Dense asphalt concrete(old)	E2: Dense asphalt concrete(old)

Experiment was done on E1 and E2

Source: Project ROSSANE

Experimental design

Infrared Temperature sensor

Sensor Specification

- Accuracy-±1°C
- Operate in ambient temperatures from 0°C to 70°C

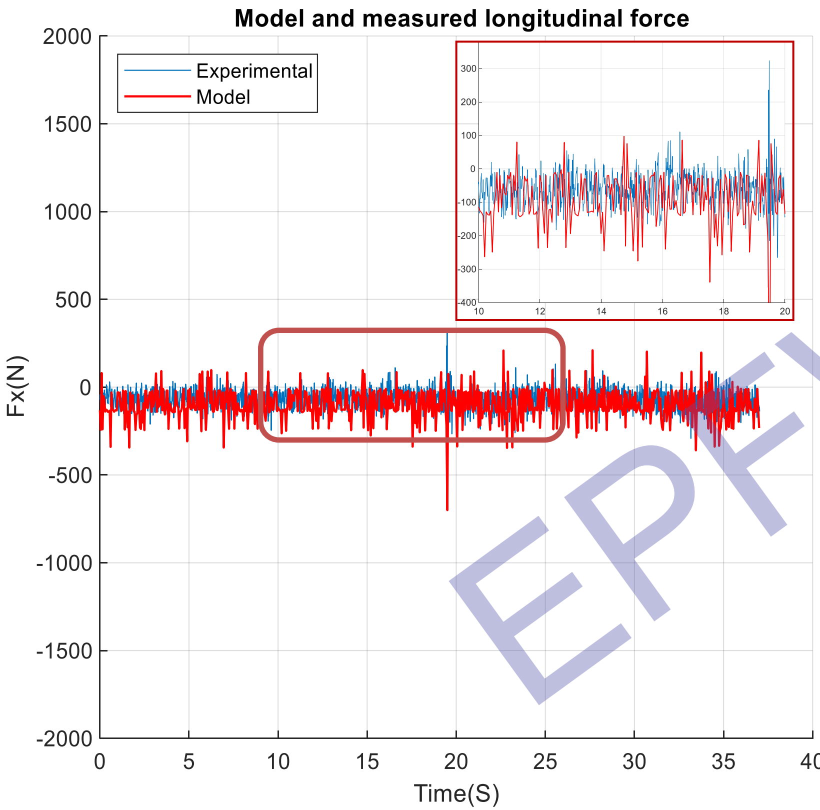
Experiment Condition

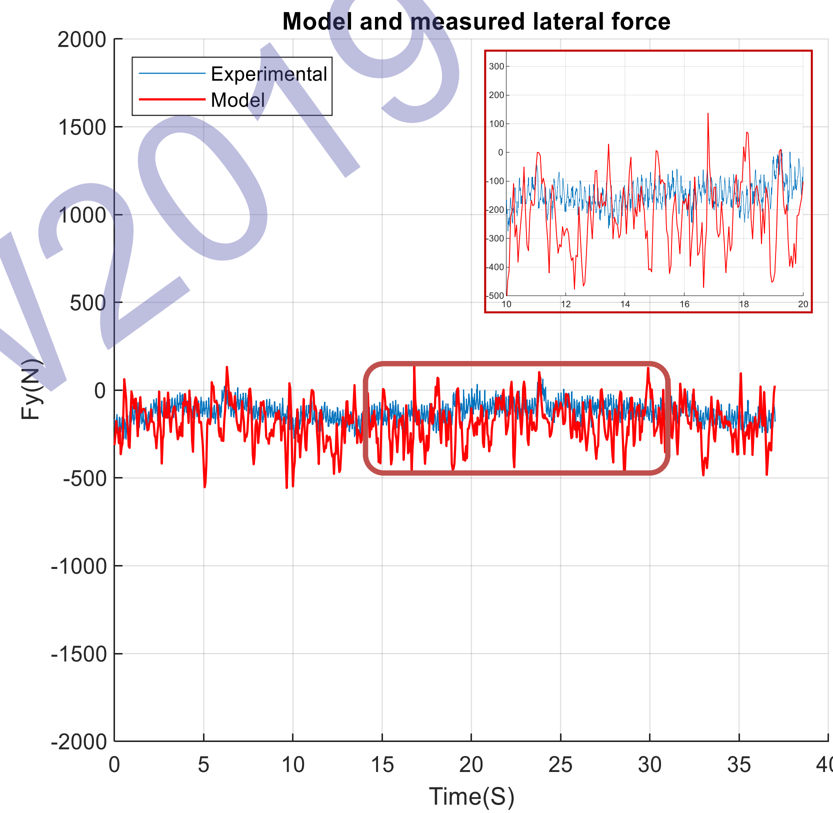
1. At constant velocity ≈50km/h
2. Accelerating from 0km/h to 115km/h and brake to 0km/h.

Experimental result(1/4)

<u>Experiment Condition</u>

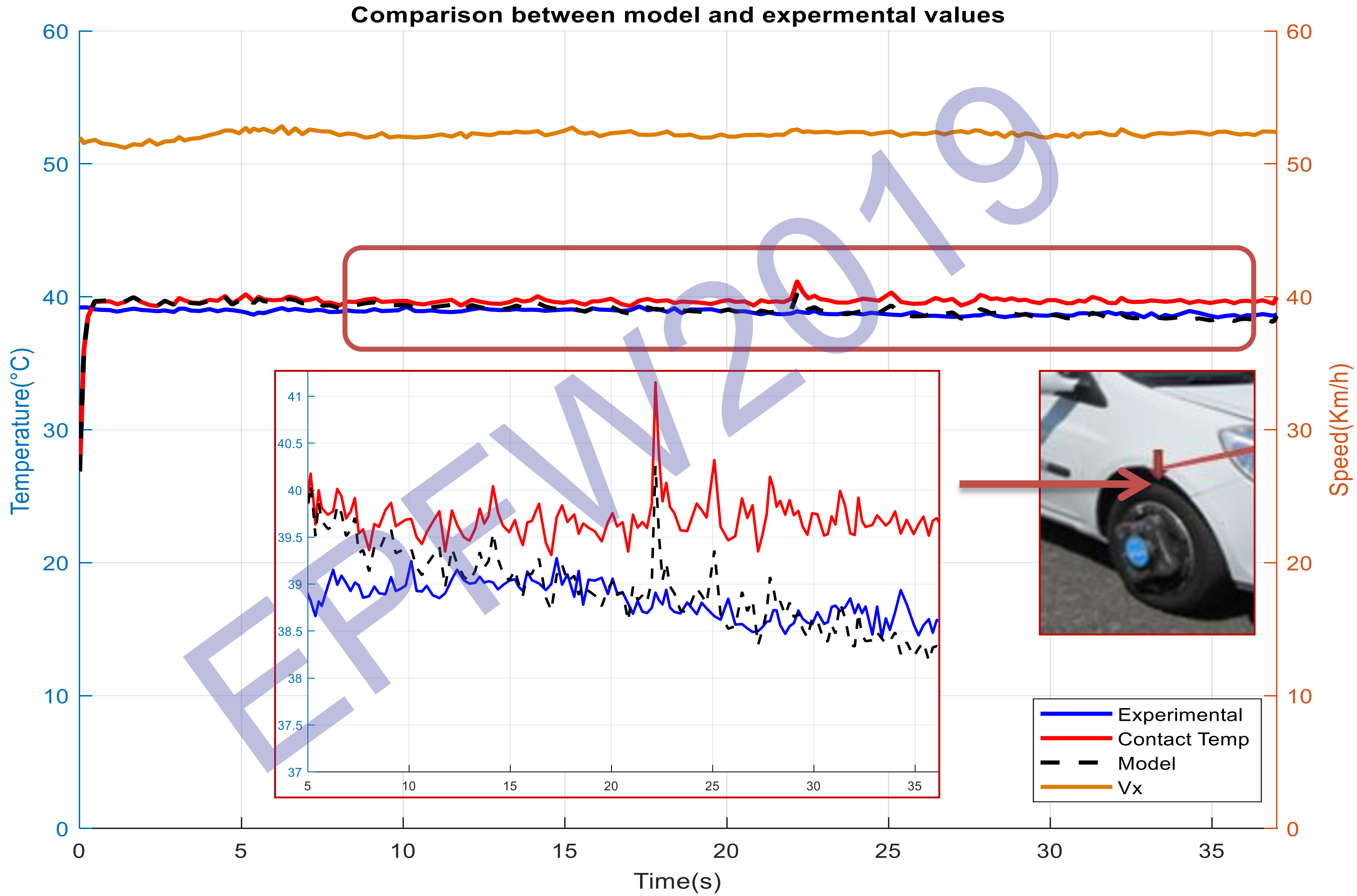
1. At constant velocity ≈52km/h
2. Straight line motion on piste E1-E2





Experimental result(2/4)

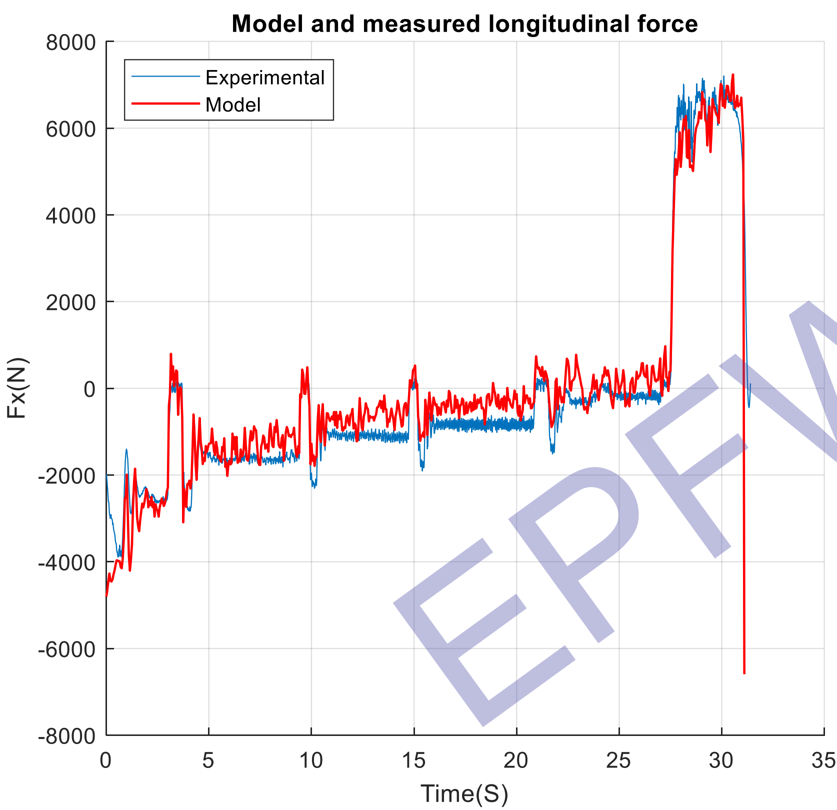
Comparison of simulation and experimental results of tread surface temperature

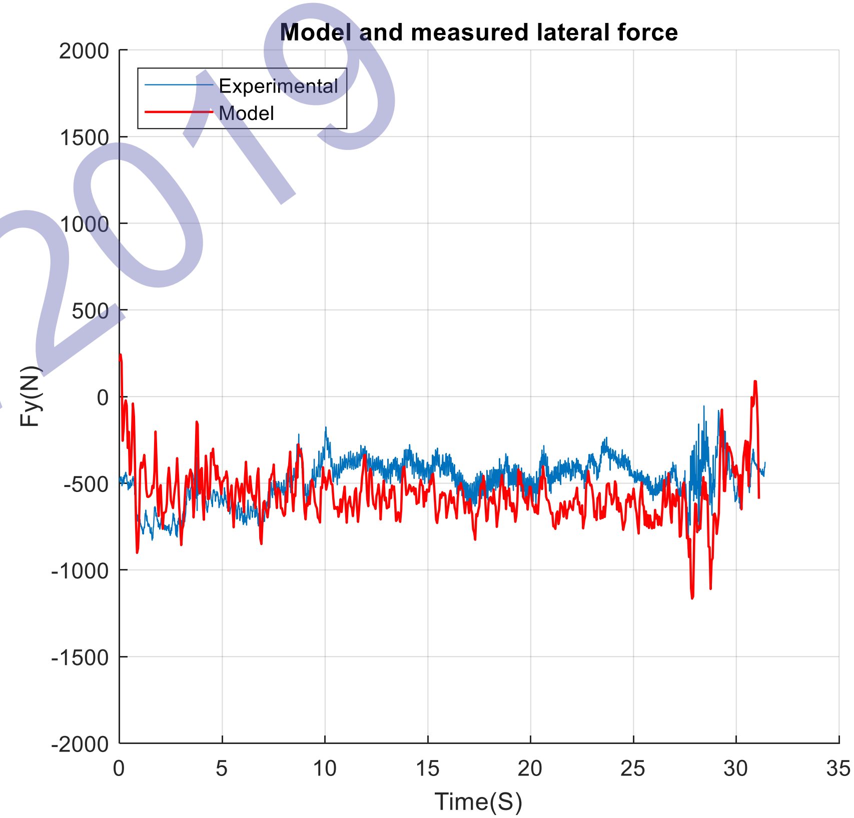


Experimental result(3/4)

Experiment Condition

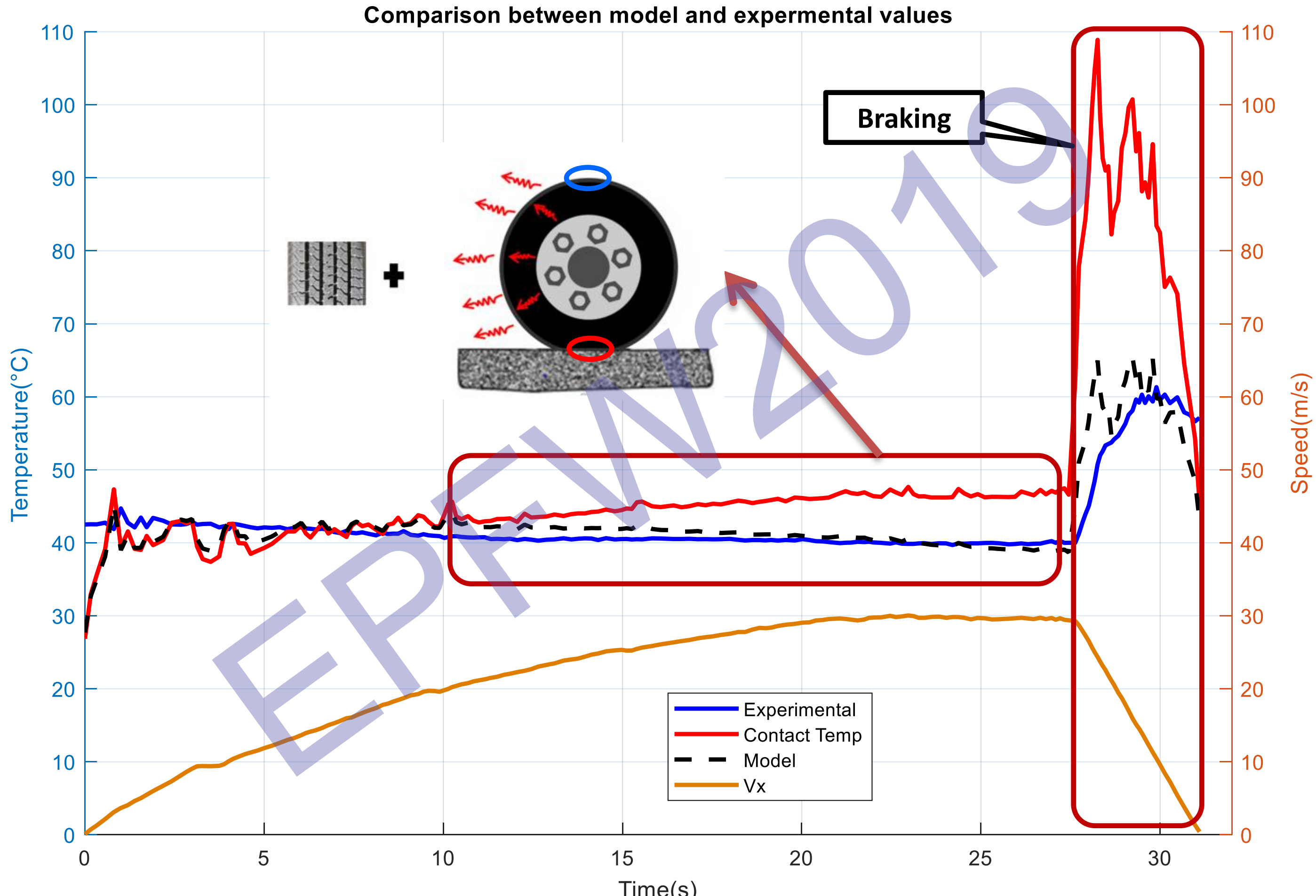
1. Accelerating from 0km/h to 100km/h and braking to 0Km/h
2. Straight line motion on piste E1-E2





Experimental result(4/4)

Comparison of simulation and experimental results of tread surface temperature



Conclusion

- Multi physical tire model is presented
  - Mechanical model with multiple contact point
  - Thermal model and its integration is presented
  - Impact of road texture is taken into account
- Validation
  - Numerical comparison
  - Experimental comparison
- Future objectives
  - Integration of hydrodynamic model
  - Implement on full vehicle model

Thank you for your attention

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