Cosimulation MotionView – ST Activate

for thermal analysis and stopping distance of a motor vehicle

Ing. Nicolò Indovina

ANKERS juss-amg: presentation

ANKERS Juss- Amg is a consulting company with a great specialisation in automotive field.

Thanks to its many years of experience in the design and development sectors, Ankers provides numerous solutions to the most challenging requirements with ad hoc projects studied in synergy with the customer to ensure efficient and innovative advice.

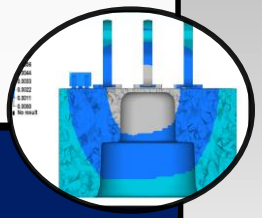
Ankers is able to provide increasingly innovative solutions, convinced that the continuous renewal and the use of most modern and

Advanced technologies are essential ingredients to

achieve the goals more ambitious.

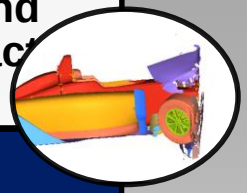
CAE competences

- Linear/non linear analysis
- Kinematics/Dynamics analysis
- Thermal analysis
- Modal analysis
- Check analysis
- Buckling
- Geometrical optimization



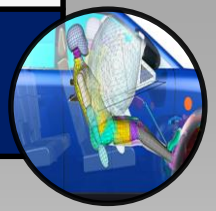
Structural analysis with Abaqus, Optistruct

- Seatbelt
- Side, rear and frontal impact
- Crash test

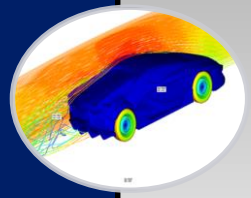


Passive Safety with Ls-Dyna, Radioss, Pamcrash, Abaqus

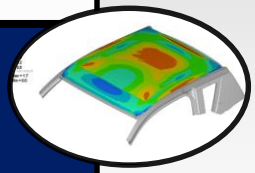
Biomechanis: sw available on demand



Vehicle Dynamics & Multibody analysis with Motion Solve, AdamsCar

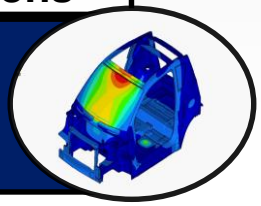


Fatigue with N-Code, FemFat



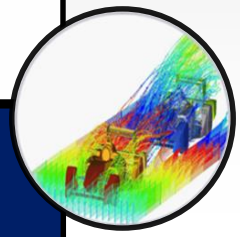
- Vibration and acustic solutions

NVH with Abaqus, Optistruct, Nastran



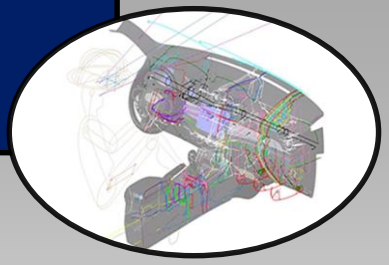
- Internal/external aerodynamic
- Flows analysis
- Aeroacoustic analysis

CFD with AcuSolve, Star CD, OpenFOAM



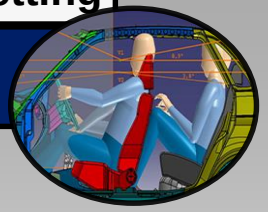
CAD competences

Technical and Legislative Feasability



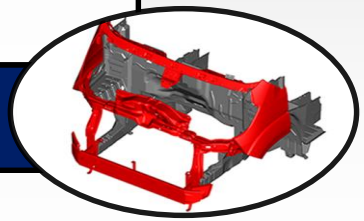
- **Habitability setting**

Ergonomy with Catia



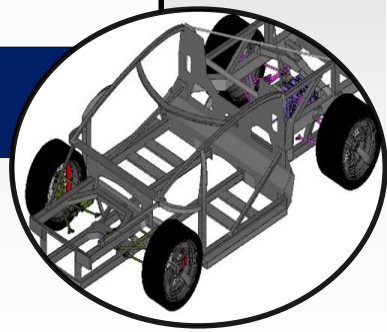
- **Body in white, closures, external trims, under and upper body**
- **Interiors trims: panels, cockpit, seats**
- **Powertrain components, gears, cooling system**

Design with Catia, NX, PTC Creo



- **Main dimension**
- **Wheel base and track**
- **Suspensions, styling brake system**
- **Dashboard macro-feasibility**

Vehicle Layout with Catia, NX



The purpose

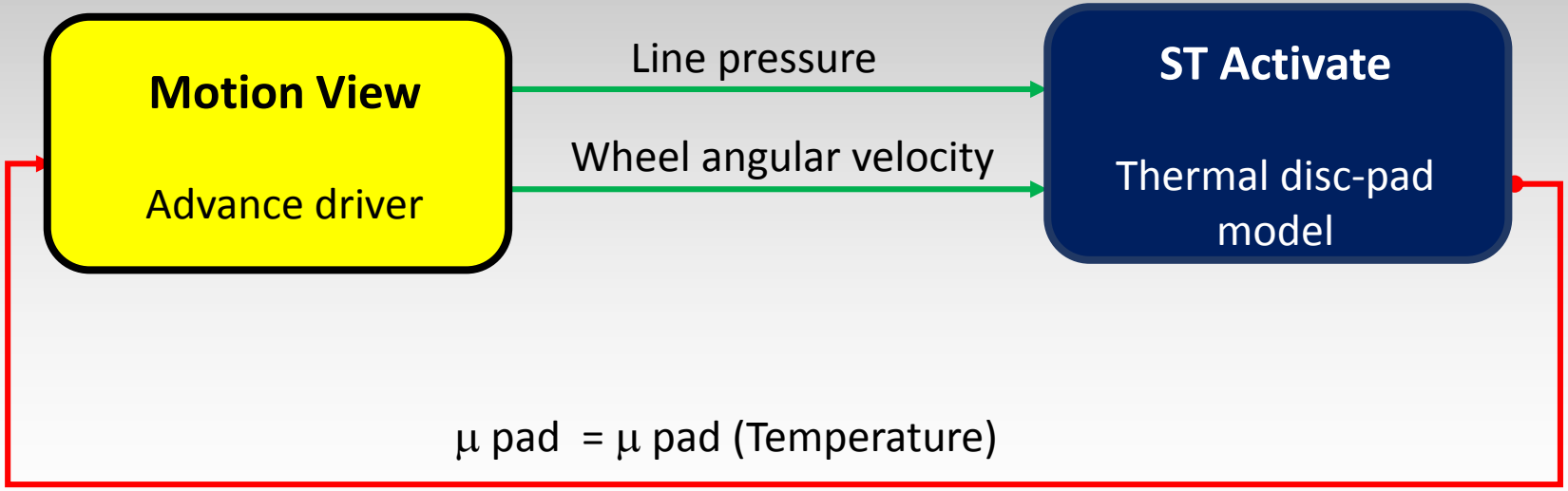
The work’s main purpose is to realize a calculation tool able to assist technicians throughout the braking system’s design during the first phases of vehicle’s layout.

In particular we want evaluate the stopping distance’s increase during the brake caused by the augment of brake pad’s temperature during the disc’s contact.

The co-simulation model layout

The tool is composed by two parts:

1) the first one is the vehicle system modeled by multibody technique with Motion View;
2) the second one is the addition of the thermal disc-pad system model realized with ST Activate.



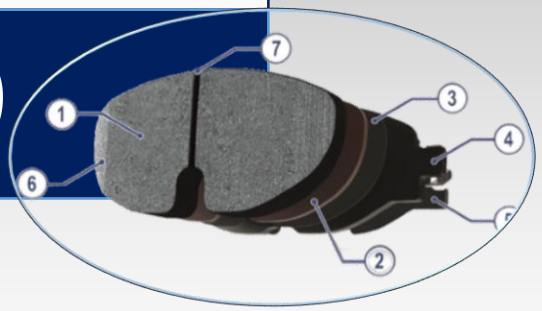
Components

- It absorbs 70 to 80 % of the heat generated during braking;
- Constructed mainly of: cast iron, aluminum and carboceramic;
- Ventilated and no ventilated disc brake.

DISC

- 1) Friction material;
- 2) Substrate;
- 3) Adhesive;
- 4) Plate;
- 5) Antivibration;
- 6) Support.

PAD

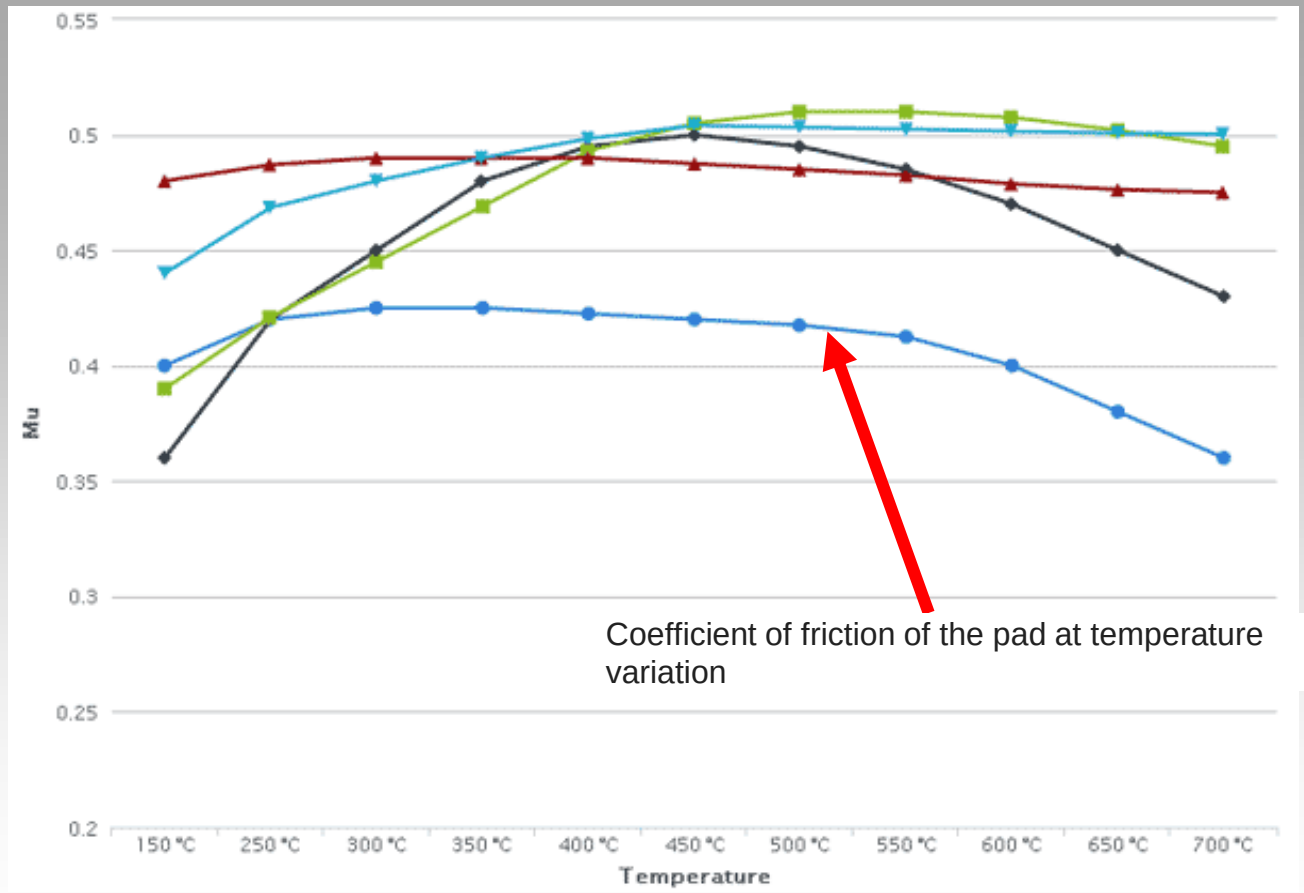


Phenomenon Study: energy transfer

KINETIC ENERGY

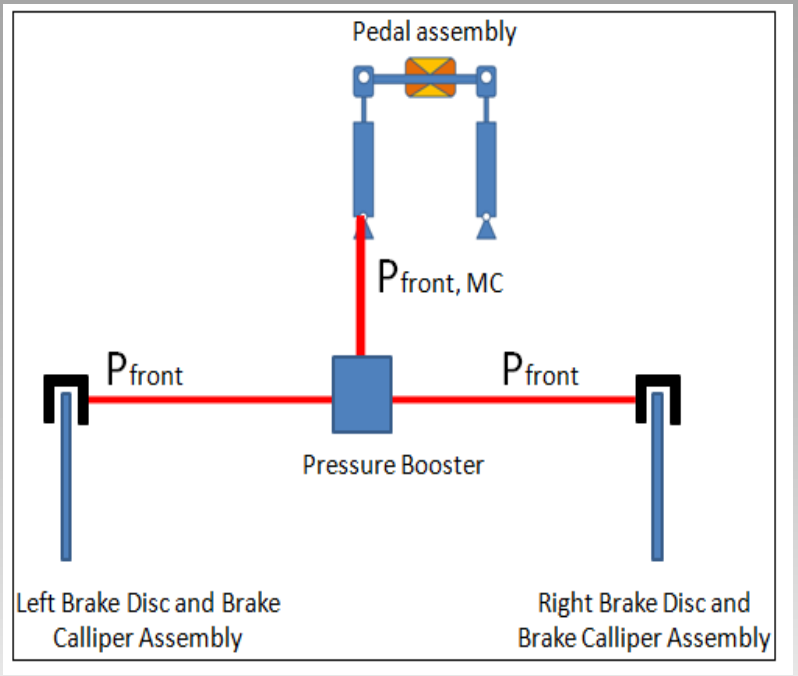
HEAT

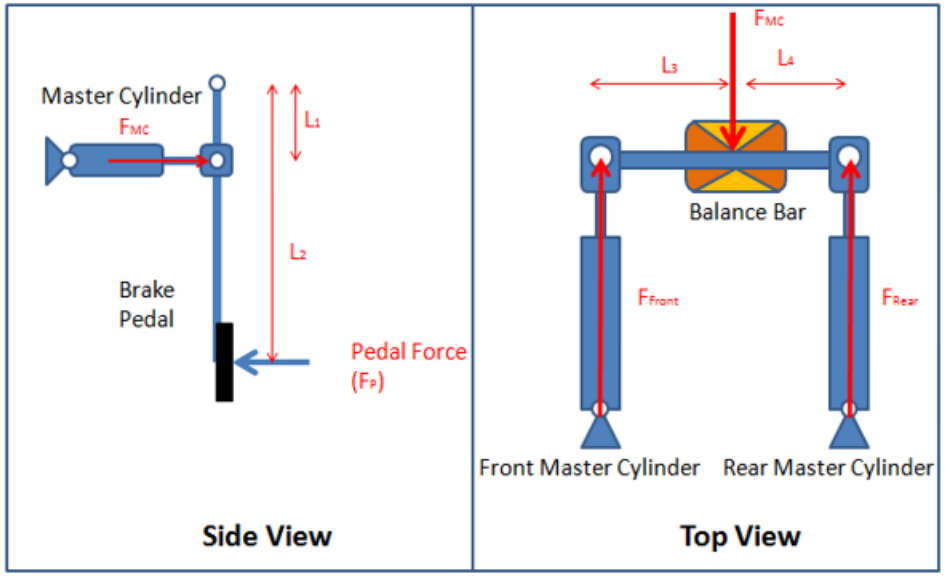
Friction coefficient of the pad from experimental test



Coefficient of friction of the pad at temperature variation

Motion View advance driver - Part. 1

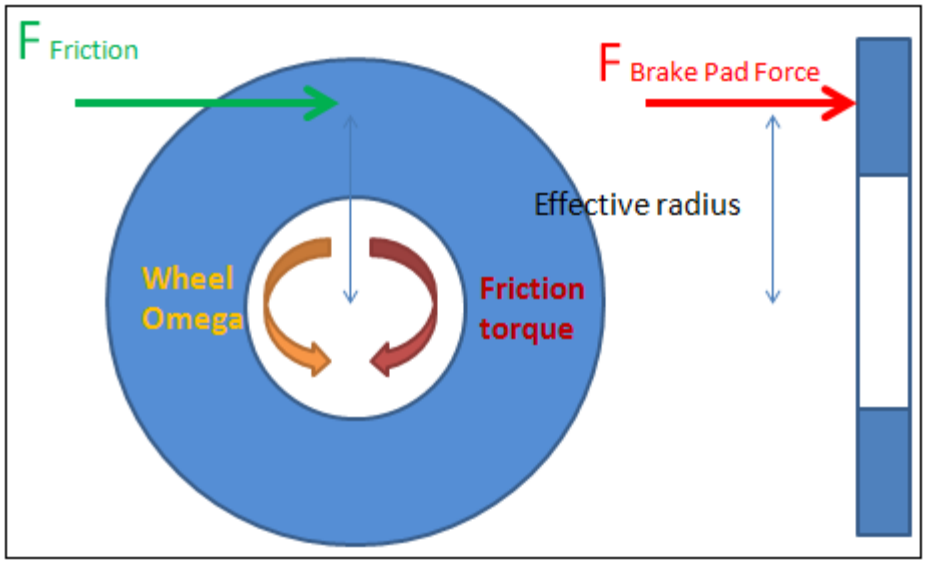




Pedal Box schematic

- Pedal force (F_P) = $\frac{F_P * \text{Brake Demand}}{F_{P,Max} * \text{Brake Demand Scaling}}$
- Pedal ratio (PR) = $\frac{L_2}{L_1}$
- Force at master cylinder mount point (F_{MC}) = PR * F_P
- Brake bias (BB) = $\frac{L_3}{L_4+L_3}$
- Force in front master cylinder, F_{Front} = BB * F_{MC}
- Pressure in front brake line, P_{Front} = $K_{Brake\ boost}$ * $F_{Front}/Area_{MC\_front}$
- Force in rear master cylinder, F_{Rear} = (1 - BB) * F_{MC}
- Pressure in rear brake line, P_{Rear} = $K_{Brake\ boost}$ * $F_{Rear}/Area_{MC\_rear}$

Motion View advance driver – Part. 2



Brake Disk schematic

Normal force by brake pad on front brake Disk:

- $F_{\text{Brake pad left}} = F_{\text{Brake pad right}} = P_{\text{Front}} * \text{Area}_{\text{brake pad}}$
- $F_{fr,Max} = \mu * F_{\text{Brake pad left}}$
- $F_{fr} = \text{STEP5}(\omega_{\text{wheel}}, -\omega_{\text{stiction}}, F_{fr,Max}, \omega_{\text{wheel}}, \omega_{\text{stiction}}, -F_{fr,Max})$

μ is friction coefficient between brake Disk and brake pad

ω_{wheel} is angular velocity of the wheel

ST activate thermal disc-pad model – Part. 1

Physical Reality

Constitutive law

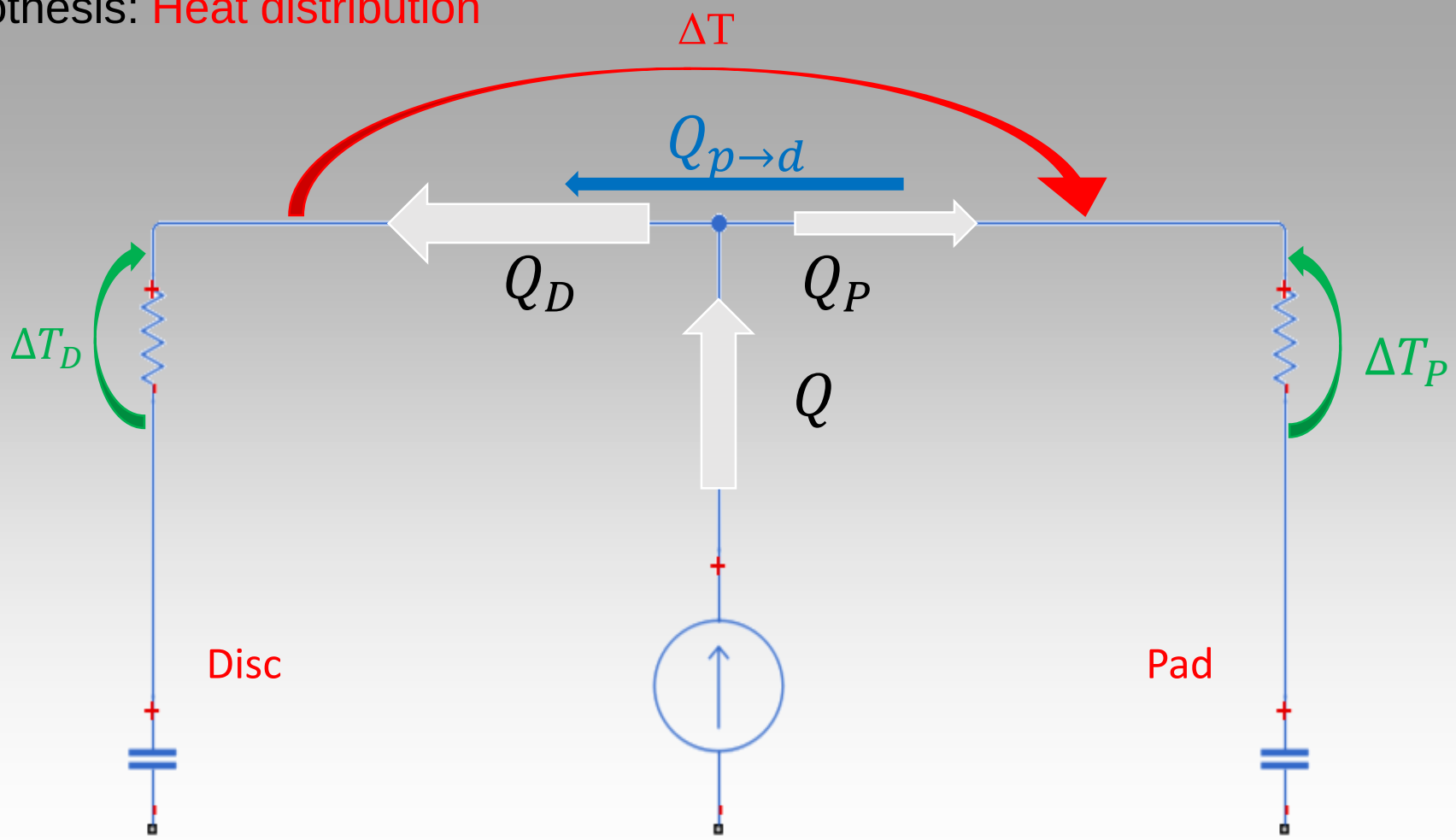
- $E_c = {}^1/_2 \left[m_{vehicle} \left(v_f^2 - v_i^2 \right) + I_{wheel} \left(\omega_f^2 - \omega_i^2 \right) \right]$
- $E_c \xrightarrow{convertita} \sum_{i=1}^{N_{pastiglie}} Q_i$
- $Q_{braking} = \int_{t_0}^{t_1} \mu \, p \, A_{pad} r_{eff} \omega_{wheel} \, dt$
- $\gamma = \frac{Q_{disc}}{Q_{pad} + Q_{disc}} = \frac{\xi_d \, S_d}{\xi_d \, S_d + \xi_p \, S_p}$

I Thermodynamic Principle:

$$Q_{disc} - Q_{cond} - Q_{conv} - Q_{irr} = \Delta U_{disc}$$
$$Q_{pad} - Q_{cond} - Q_{conv} - Q_{irr} = \Delta U_{pad}$$

ST activate thermal disc-pad model – Part. 2

Hypothesis: Heat distribution



ST activate thermal disc-pad model – Part. 3

Hypothesis

Model

P.P.T. → Connection between heat and temperature

$$Q_{disc} - Q_{cond} - Q_{conv} - Q_{irr} = \Delta U_{disc}$$

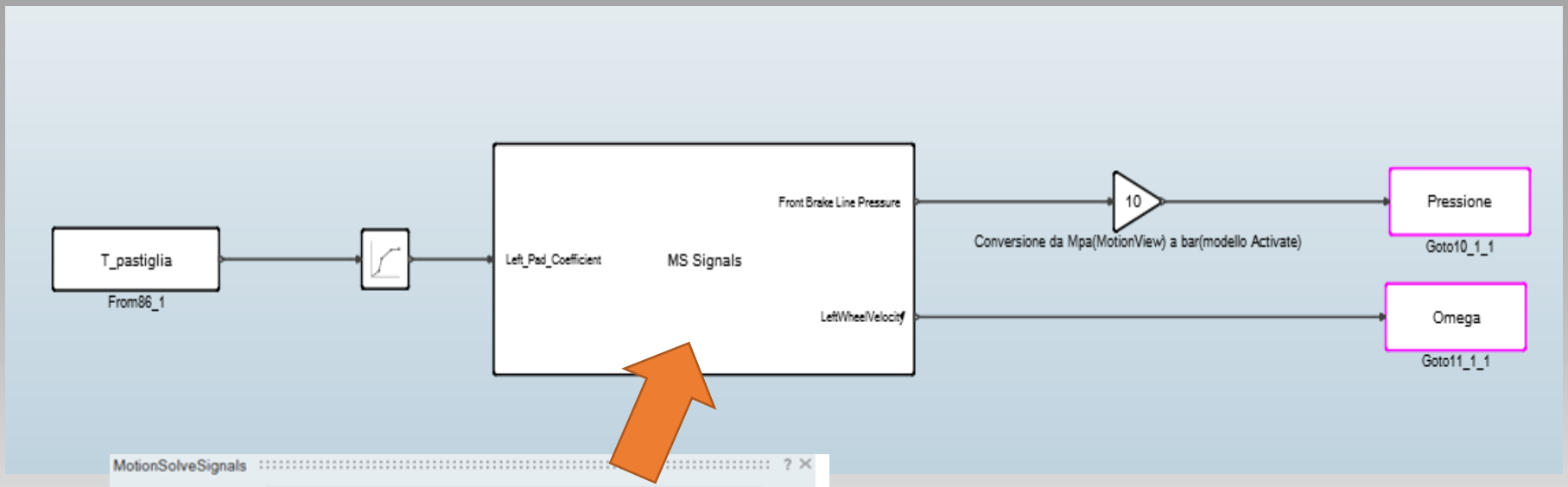
$$Q_{pastiglia} - Q_{cond} - Q_{conv} - Q_{irr} = \Delta U_{pad}$$

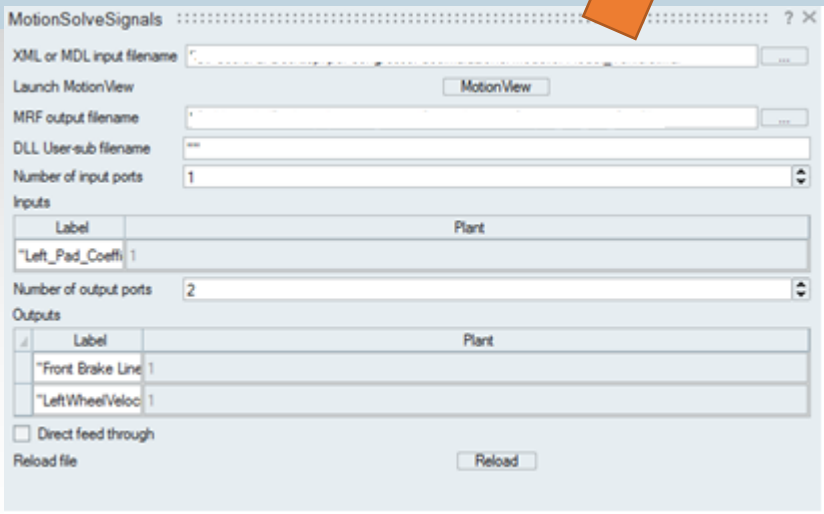
Real time thermal analysis → Simple model

$$T_{D,P} = f(r, \vartheta, z)$$

Analysis of 3D model results by other authors

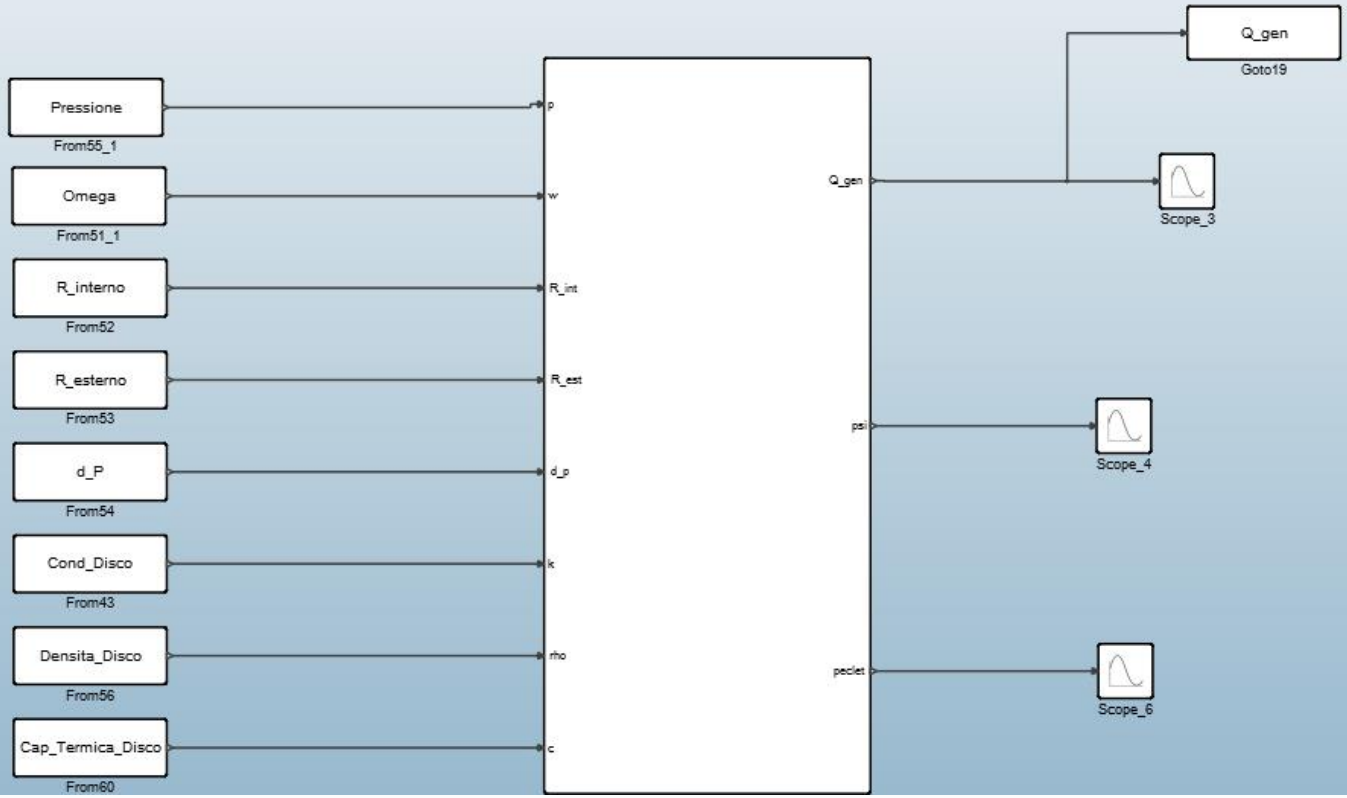
ST activate thermal disc-pad block diagram – Part. 1



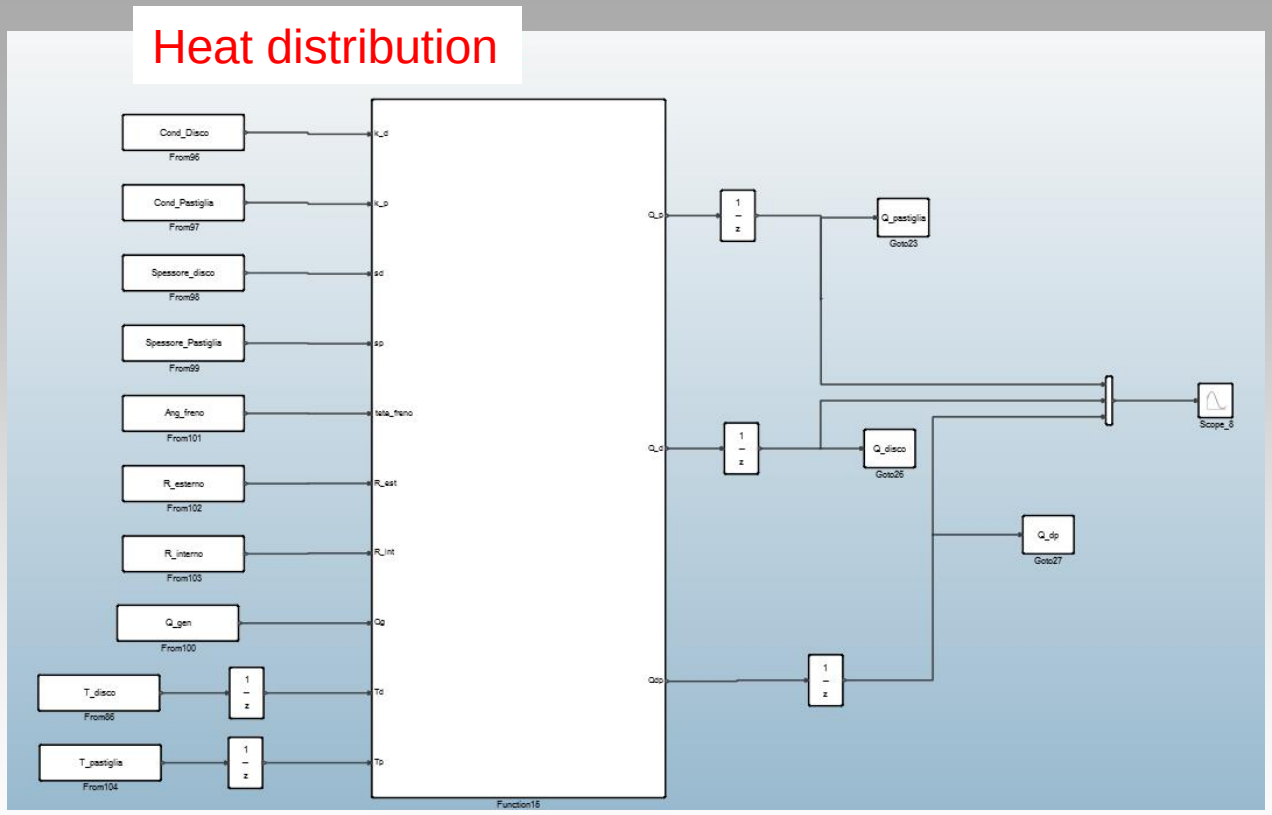


ST activate thermal disc-pad block diagram - Part. 2

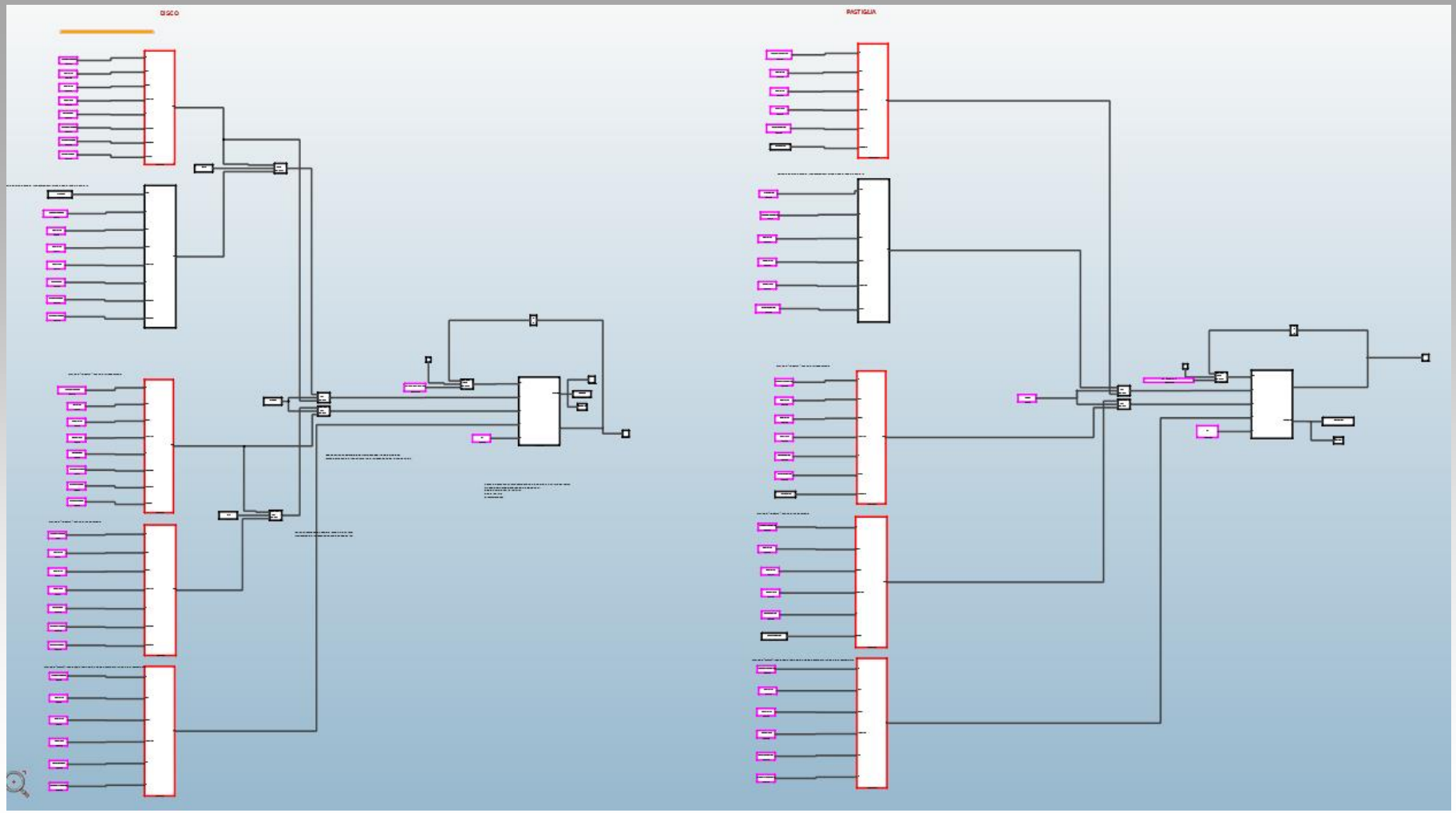
Heat generated in the unit of time



ST activate thermal disc-pad block diagram - Part. 3



ST activate thermal disc-pad block diagram - Part. 4



Comparison with 3D Model: input data

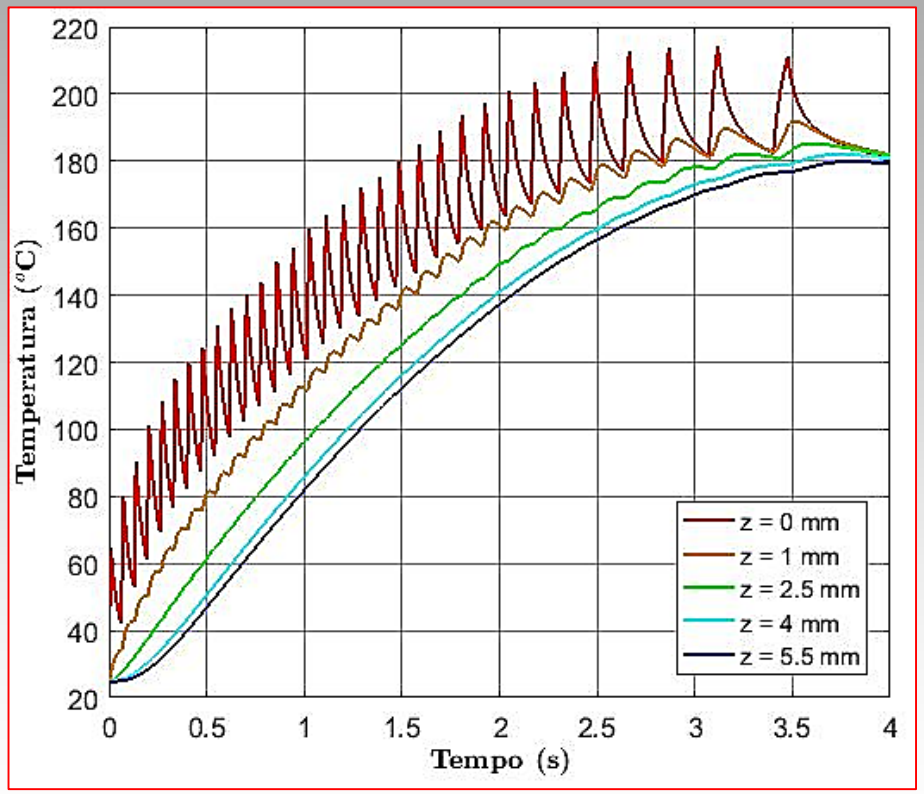
Geometry		
Parameter	Value	S.I.
Disc Inner diameter	132	mm
Disc Outer diameter	227	mm
Overlap angle	60	°
Disc thickness	11	mm
Pad thickness	10	mm
Average radius of friction	94,5	mm
Friction band	37	mm

Material property			
Parameter	Disc	Pad	S.I.
Thermal conductivity	43,5	12	W/(m K)
Density	7850	2500	kg/m^3
Specific thermal capacity	445	900	J/(kg K)

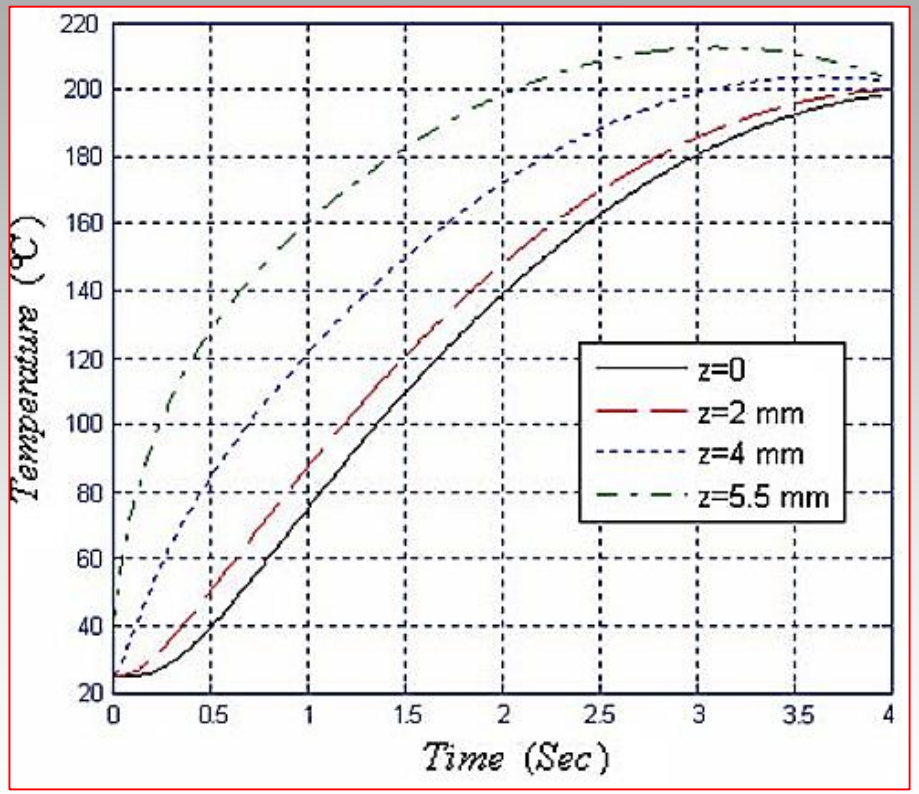
Braking test data		
Parameter	Value	S.I.
Pressure line	23,7	bar
Initial speed	100	km/h
Deceleration	7	m/s^2
Braking time	3,96	s
Totale energy	165	kJ

Comparison with 3D Model: results temperature along the disc thickness

ST Activate

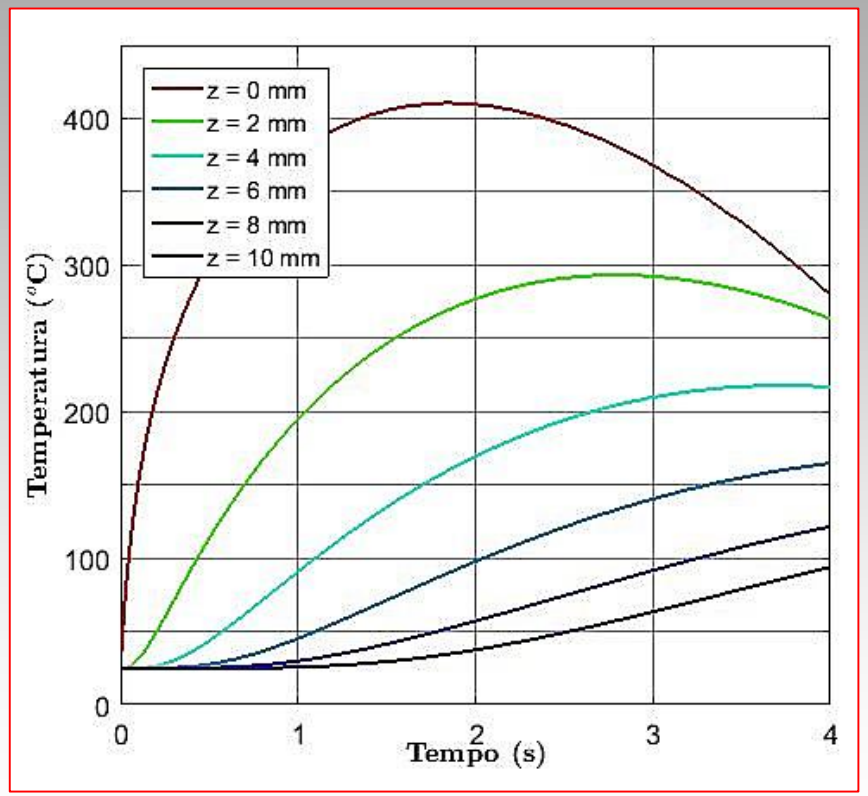


3D model

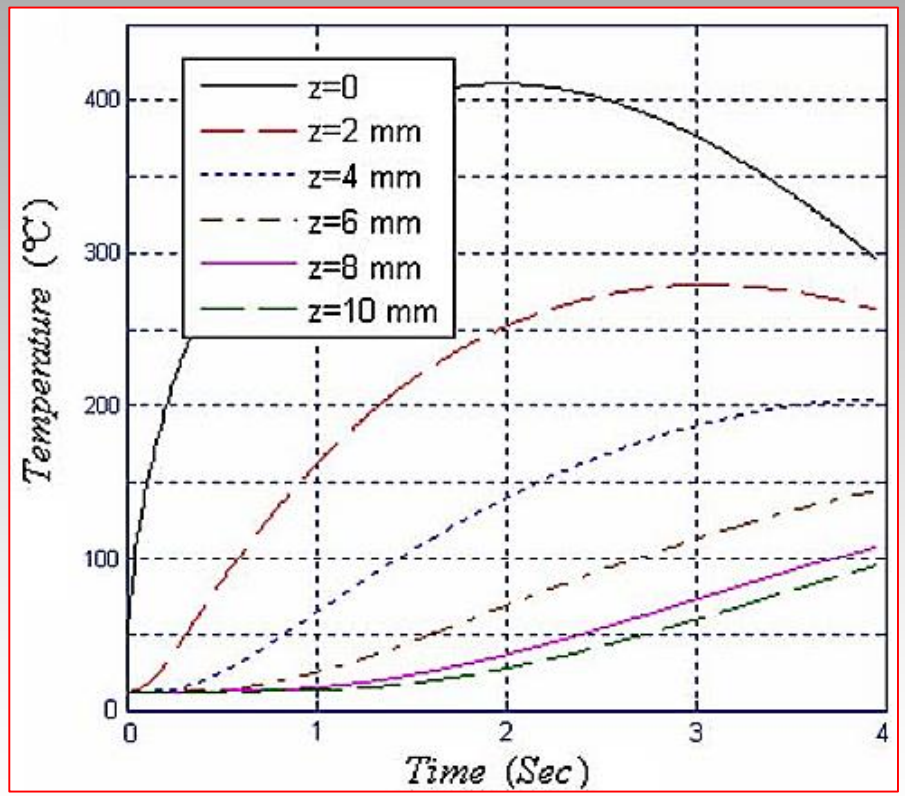


Comparison with 3D Model: results temperature along the pad

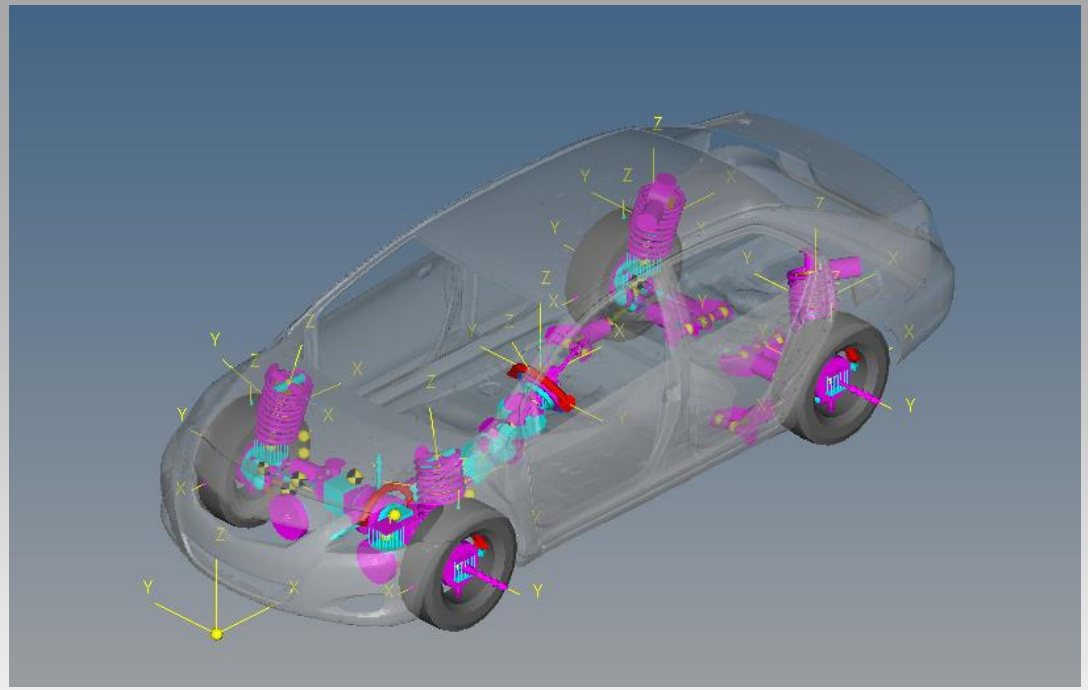
ST Activate



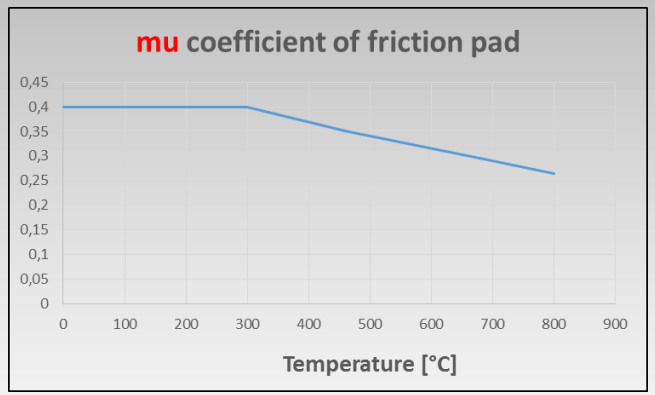
3D model



Simulation results: input data



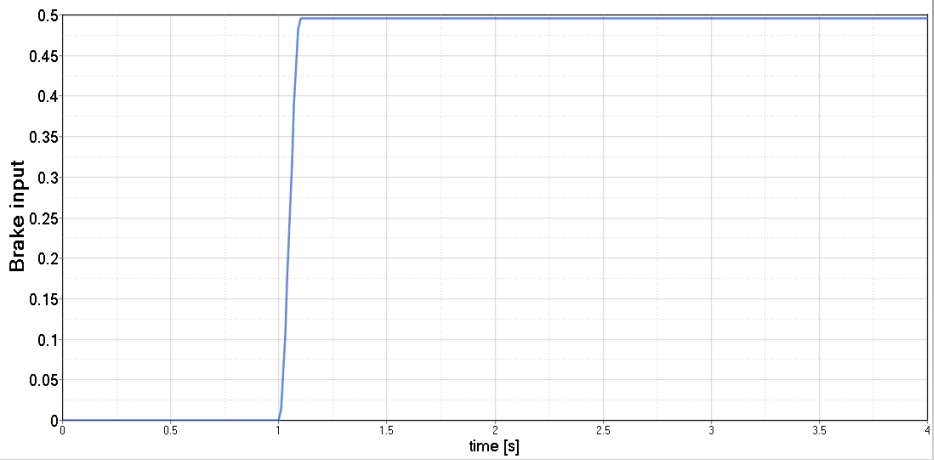
Left disk Effective Radius	260.0000
Right disk Effective Radius	260.0000
Left Piston Area	8000.0000
Right Piston Area	8000.0000
Left Pad Coefficient of Friction	0.4000
Right Pad Coefficient of Friction	0.4000



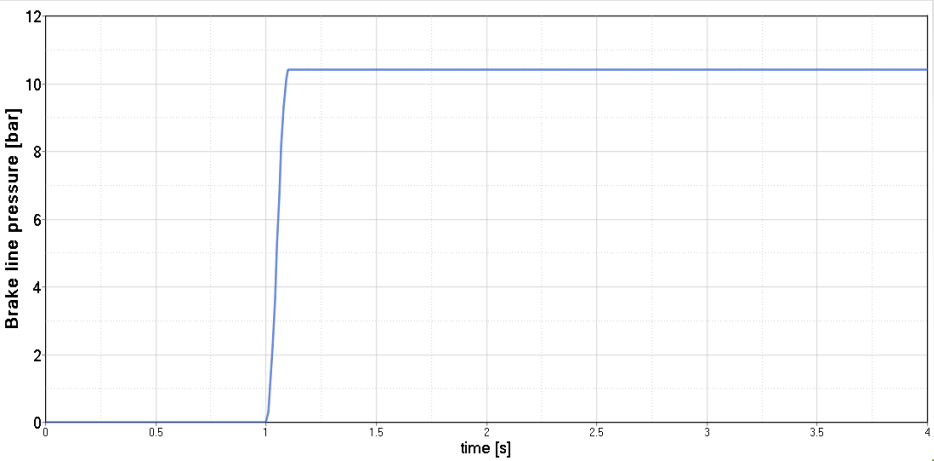
Pedal Ratio	real_pedal_ratio	Real	3.5000
Front Master Cyl Piston Area	real_front_mc_piston_area	Real	500.0000
Rear Master Cyl Piston Area	real_rea_mc_piston_area	Real	500.0000
Maximum Pedal Force	real_max_pedal_force	Real	500.0000
Brake Demand Scaling Factor	real_brake_scaling_factor	Real	1.0000
Brake Boost ratio	real_brake_boost_ratio	Real	1.0000

Simulation results: output data – Part. 1

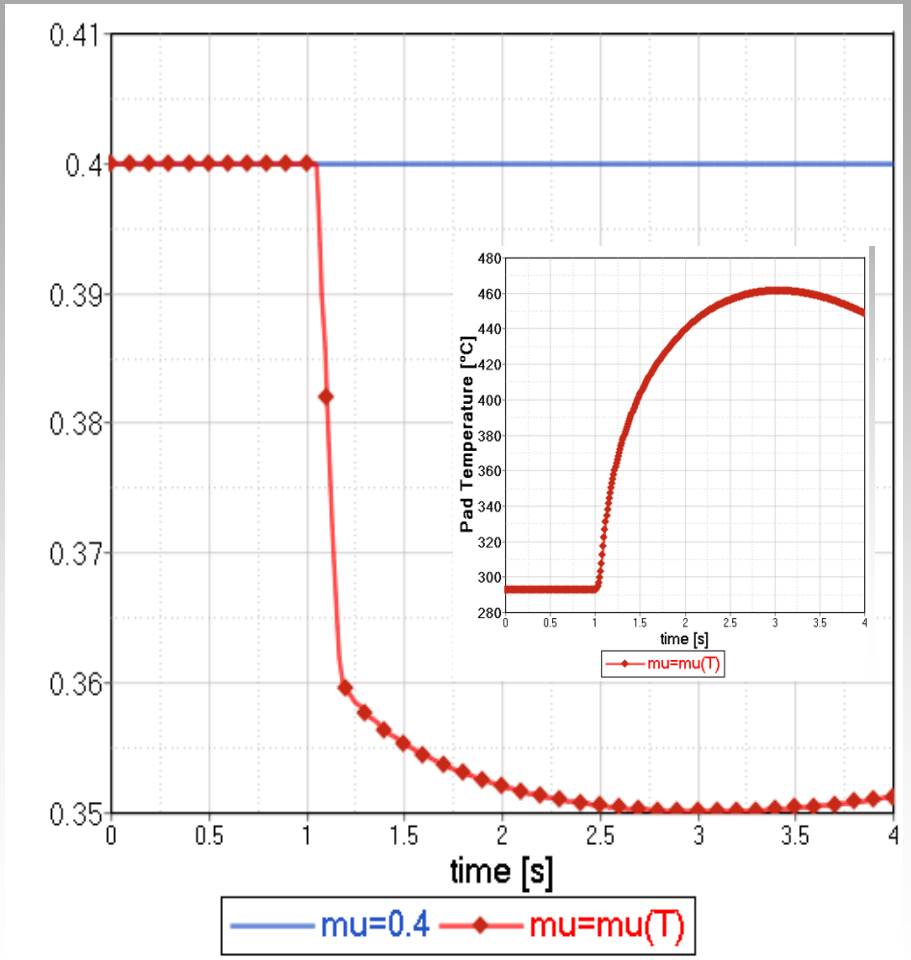
Driver's brake input



Brake line pressure of the braking system

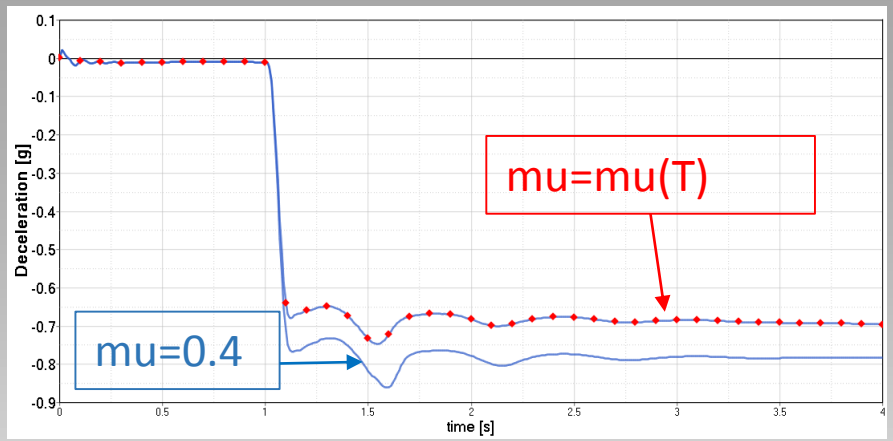


Friction coefficient

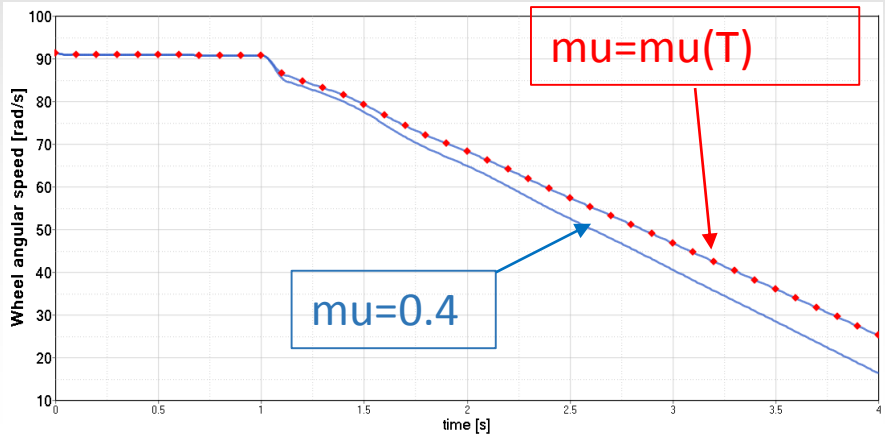


Simulation results: output data – Part. 2

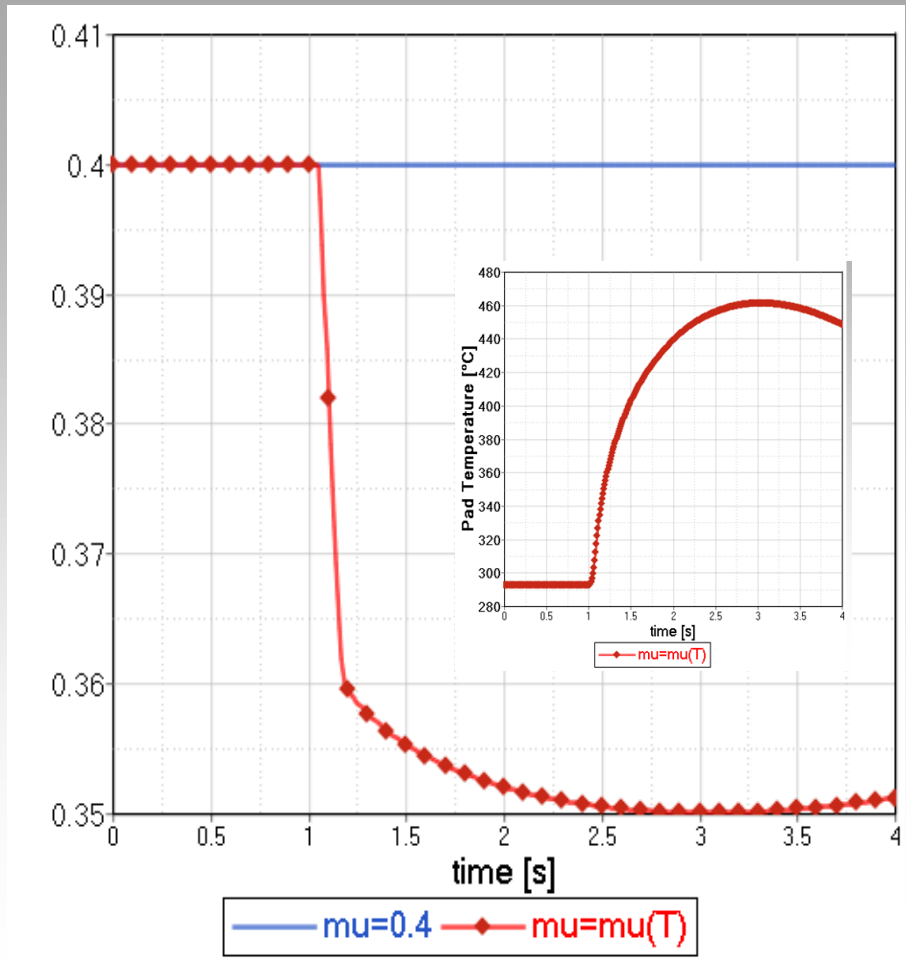
Vehicle deceleration



Front Wheel angular speed

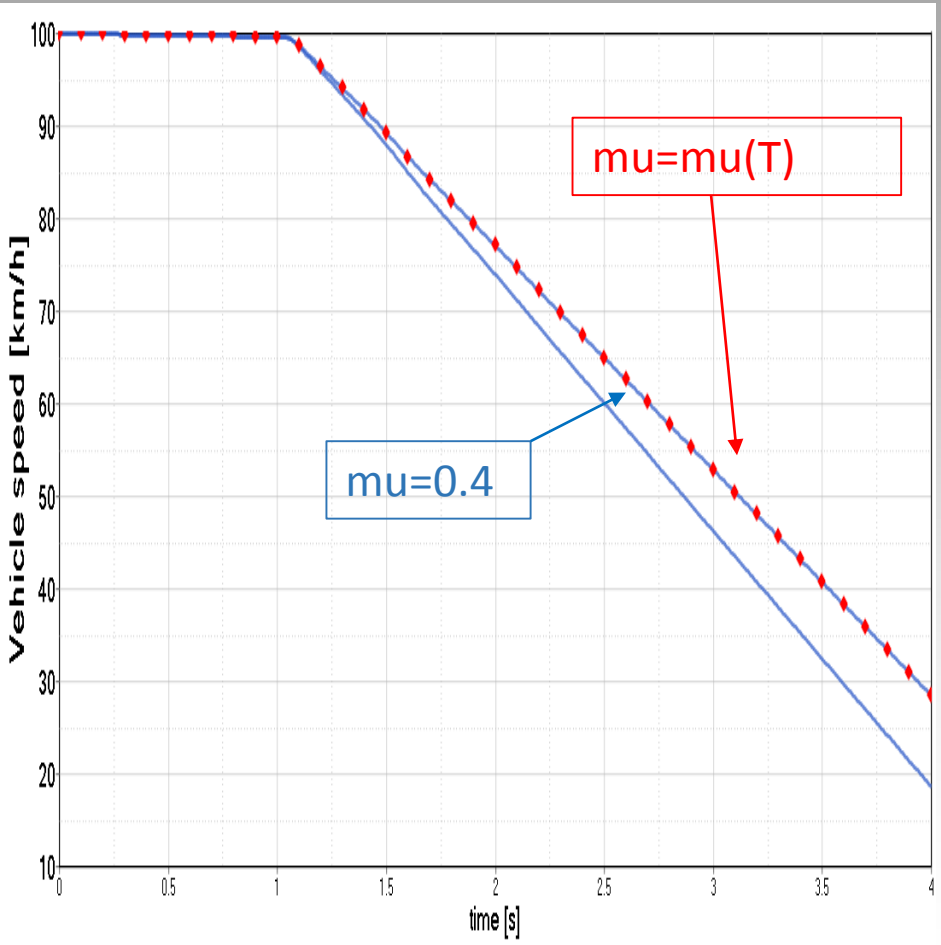


Friction coefficient

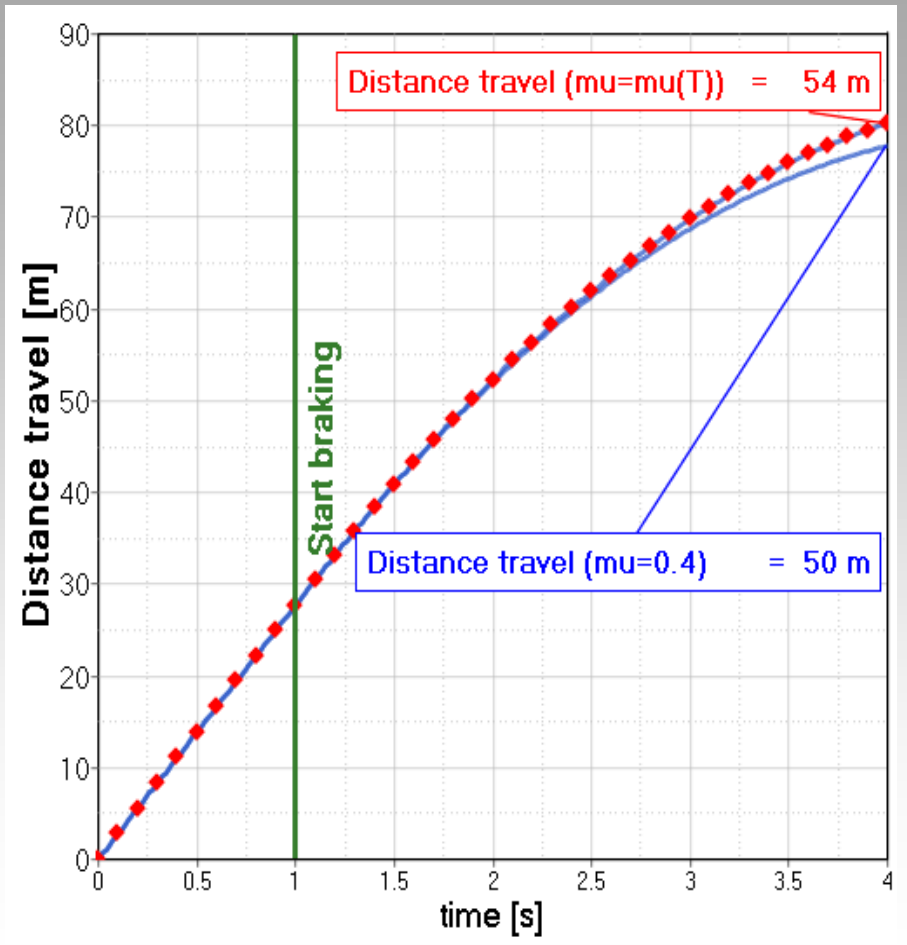


Simulation results: output data – Part. 3

Vehicle Speed

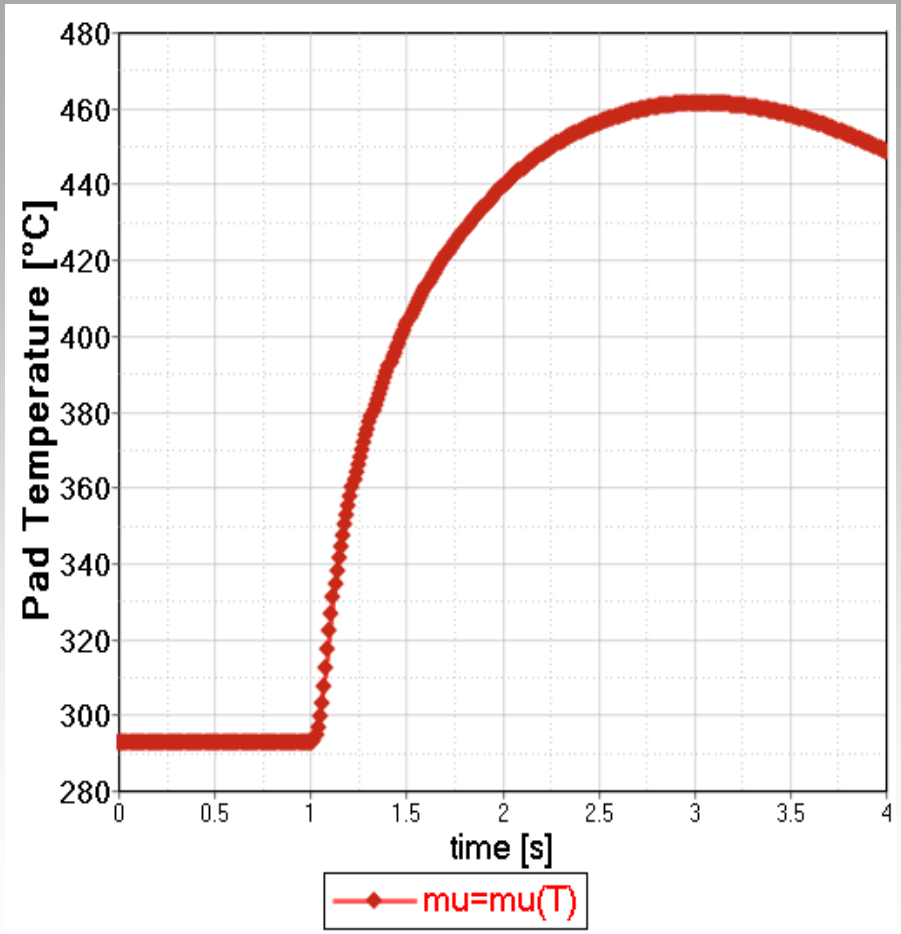


Distance travel

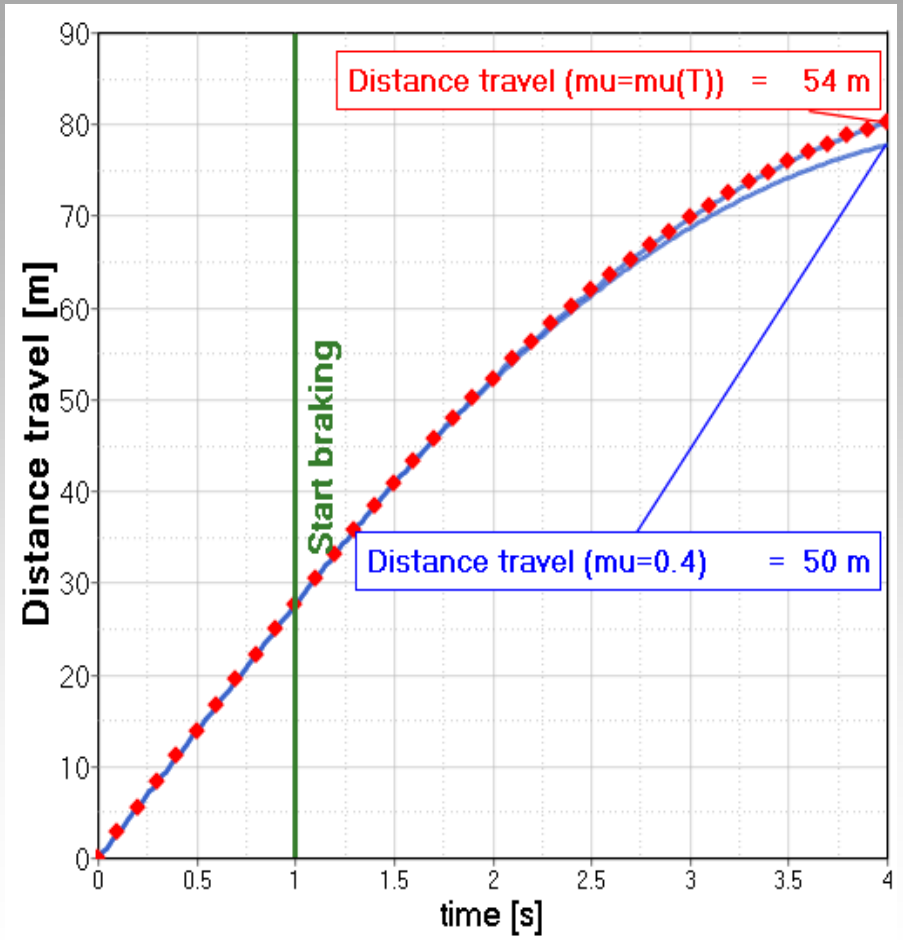


Simulation results: output data – Part. 4

Pad Temperature



Distance travel



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Thanks for the attention