AERODYNAMICS OF TRANSPORT VEHICLES

Prof. Luigi Vigevano and Prof. Paolo Schito

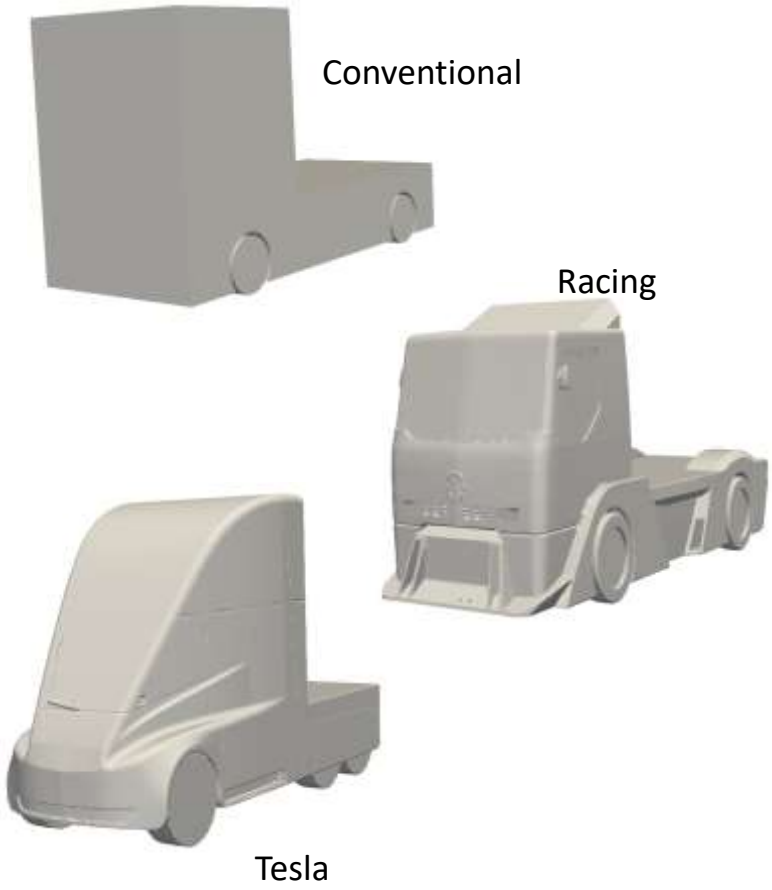
A DRAG ORIENTED OPTIMIZATION OF RACE TRUCKS

ADITYA RAMAN
MATTEO FRESCHI
RICCARDO MIOLO

POLITECNICO
MILANO 1863

GOALS

- To Optimise the Aerodynamics of Conventional truck for performance improvement
- To conduct a preliminary analysis on a real time racing truck and a futuristic model
- Development of a numerical code to simulate lap times



PROBLEM SETUP

Tools Employed:

- OpenFOAM for CFD simulation
- Paraview for Visualisation
- MATLAB for post-processing

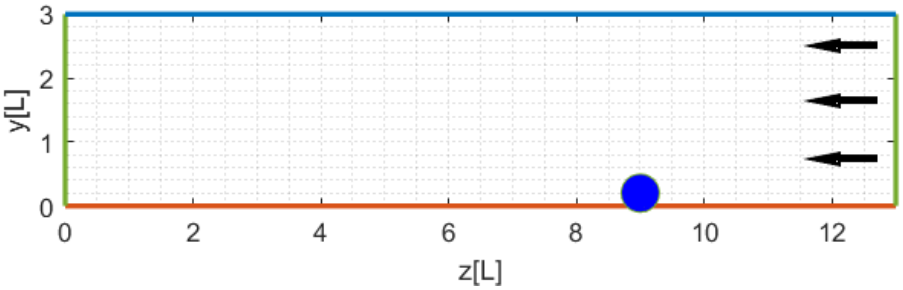
Problem Characterization:

- Speed of 100 km/hr, incompressible
- Wake: an important characterization
- Need for turbulent model: K-omega SST

SimpleFOAM: A steady state incompressible solver

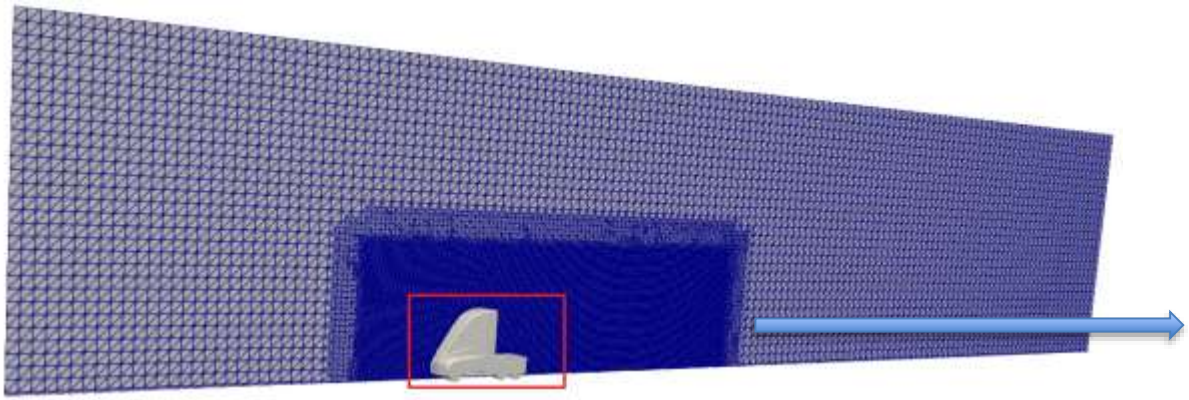
COMPUTATIONAL SETUP : BOUNDING BOX

Model	Length[m]	Breadth[m]	Height[m]
Conventional	6.04	2.55	3.64
Racing	6.04	2.55	3.55
Tesla semi	6.32	2.59	3.96



- Upstream : 4 times Length
- Downstream: 9 times Length
- Lateral vertical : 3 times Length

COMPUTATIONAL SETUP: MESH AND BOUNDARY CONDITIONS



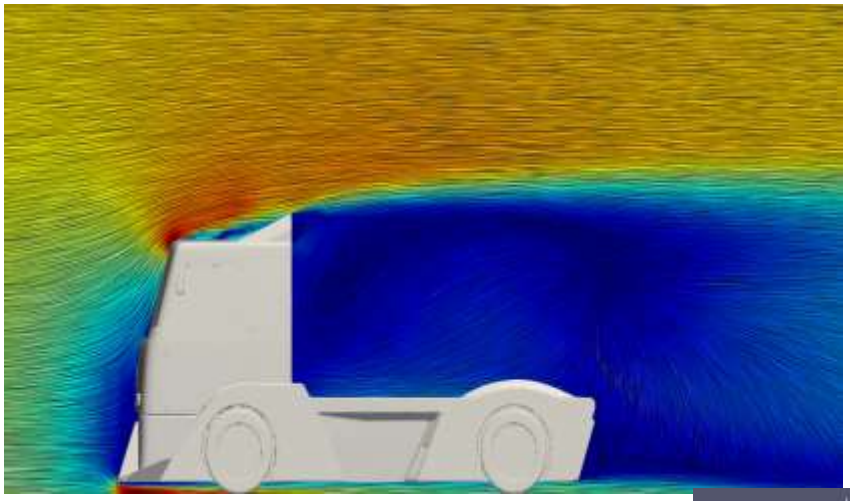
Further refinement boxes placed to capture wake

Imperfection of wheels to resemble flattening due to heavy weights

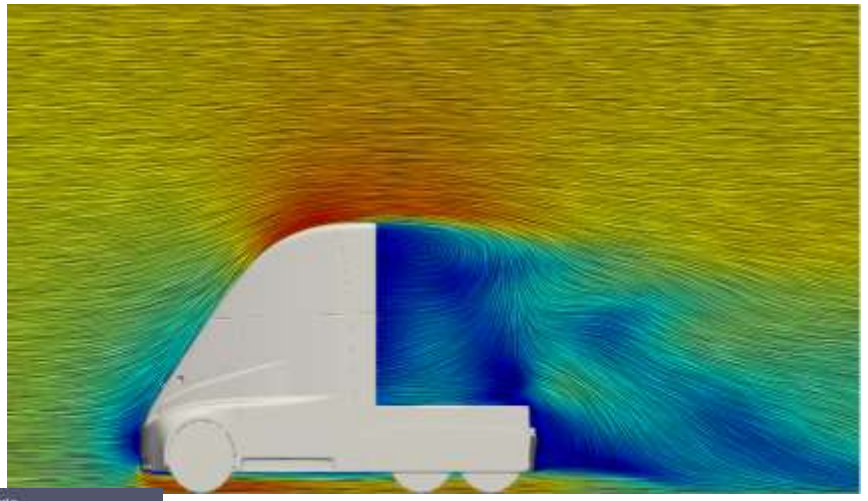
- Inlet/Outlet: Uniform
- Ground: Slip for not moving the grid

  On the surface: No slip

PRELIMINARY RESULTS : STREAMLINE VISUALIZATION



Racing truck

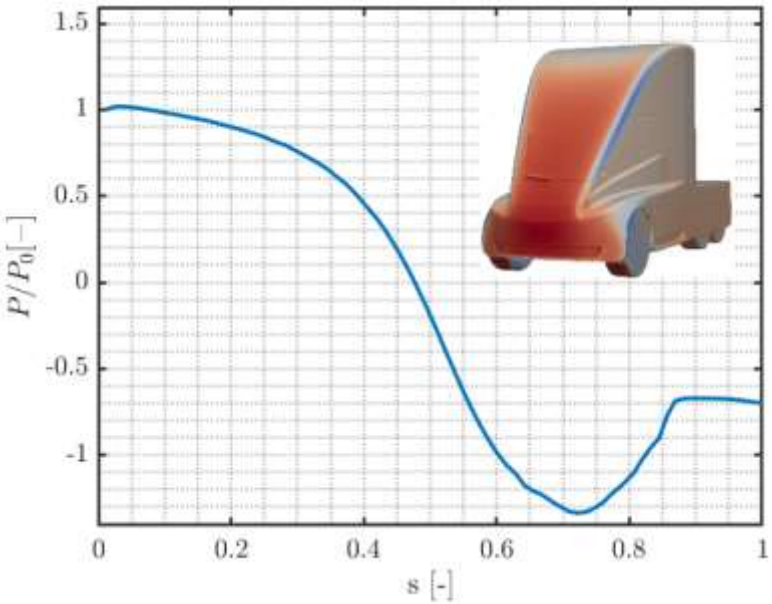


Tesla semi

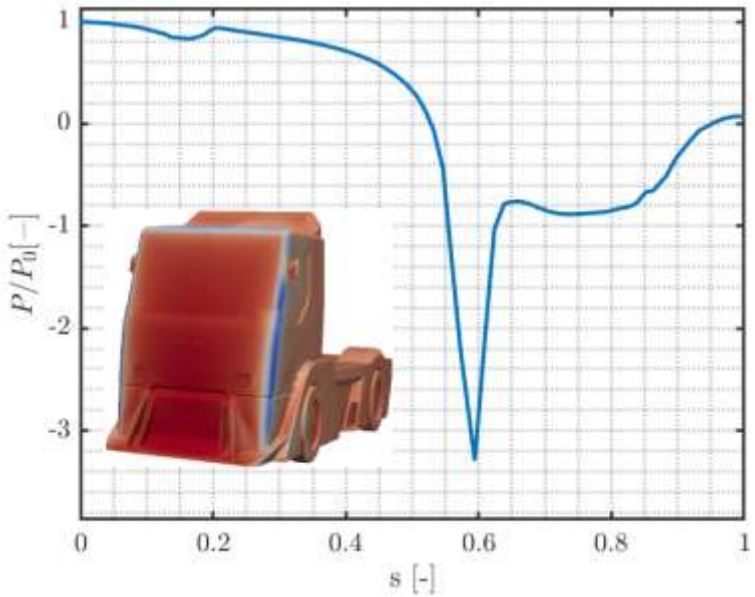
A strong recirculation region for racing truck attributed to spoilers

A streamlined frontal shape for Tesla-semi

PRELIMINARY RESULTS : PRESSURE DISTRIBUTION



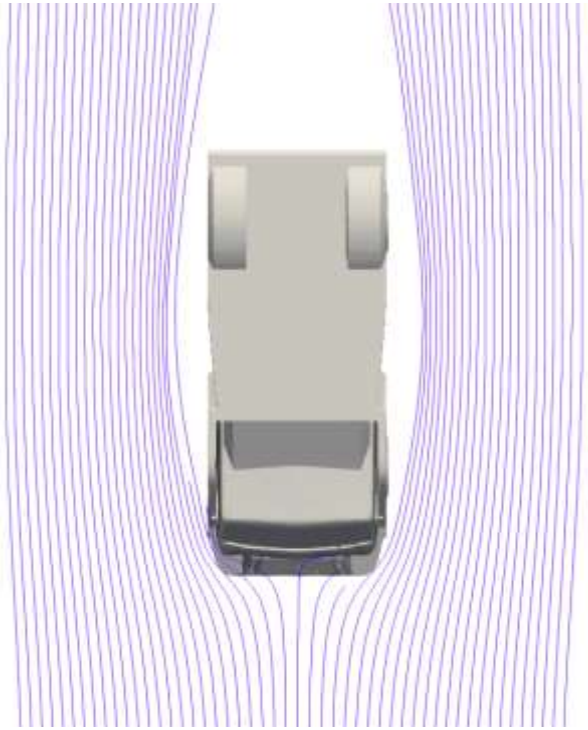
Tesla semi



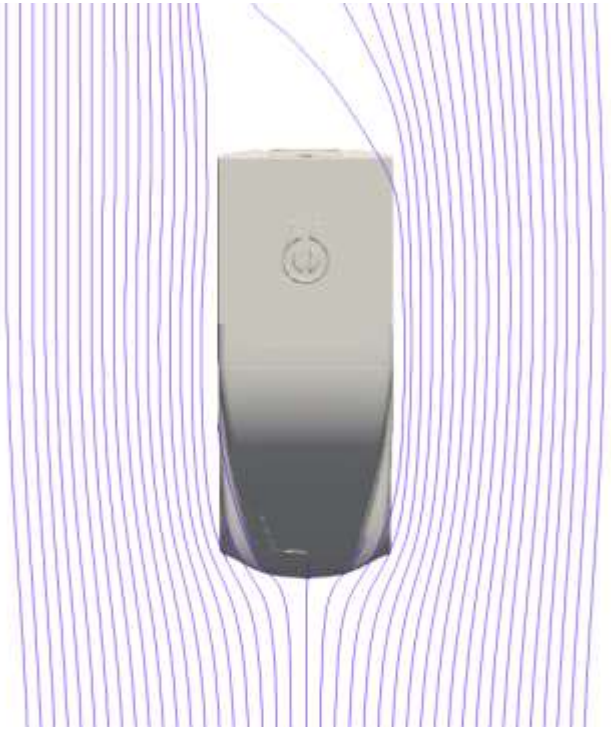
Racing

- Smoother evolution in the case of Tesla semi
- Pressure dip peak sooner for racing truck

PRELIMINARY RESULTS : STREAMLINE VISUALIZATION



Racing Truck



Tesla Semi

- A wider seperation in the case of Racing truck
- Tapered geometry of Tesla semi allows air to follow the shape

PRELIMINARY RESULTS (DRAG) AND MODIFICATIONS

$$C_D = \frac{D}{1/2\rho u^2 A}$$

Density : 1.225 Kg/m^3
Velocity: 27.78 m/s

	Racing Truck	Tesla semi
Cd	0.76	0.41

Modifications to be made:

- Round edges to avoid large recirculation
- Absence of roof spoilers

THE RE-SHAPING STRATEGY

Strategy Pillars:

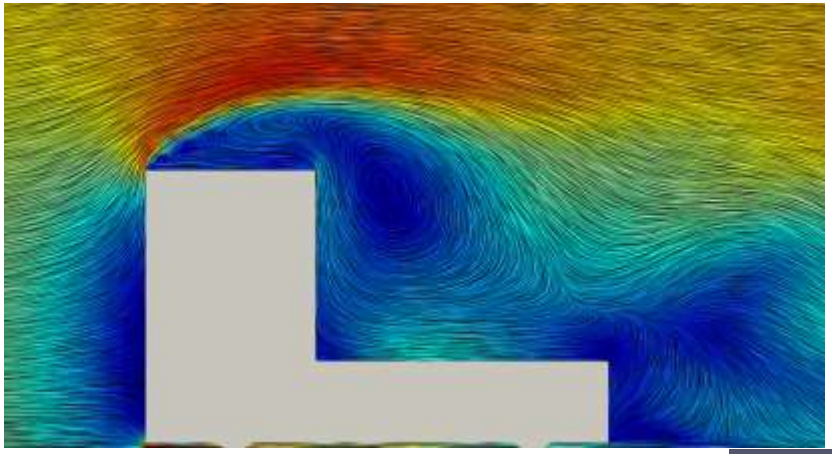
1. Shape modifications beyond regulations;

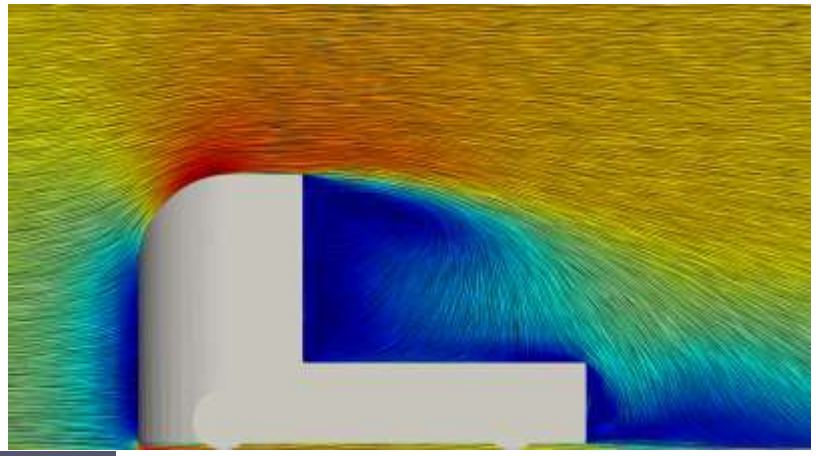
   THOUGH:

2. No extreme configuration change.

Solution

CONVENTIONAL BASIC VS MODIFIED I

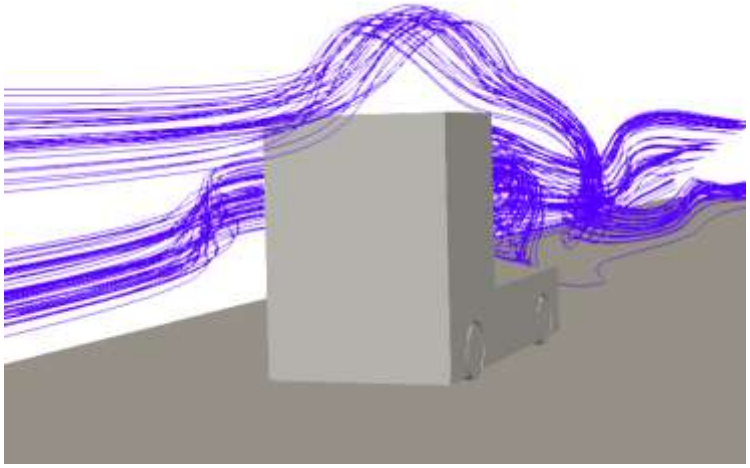


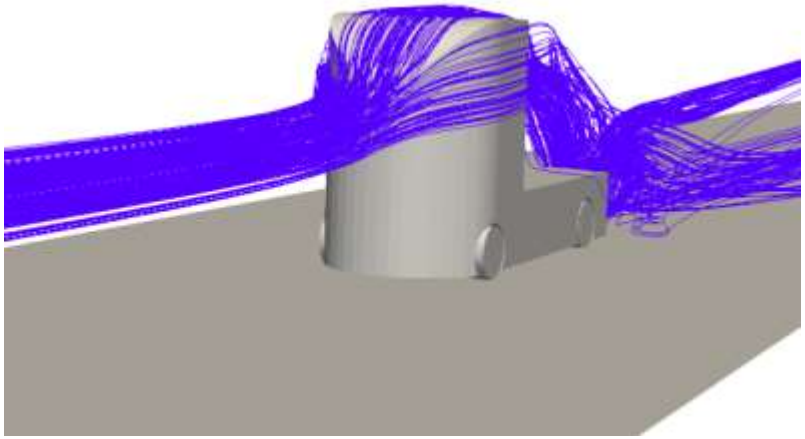


IMPROVEMENT 1:

AVOIDED TOP EDGE SEPARATION

CONVENTIONAL BASIC VS MODIFIED II

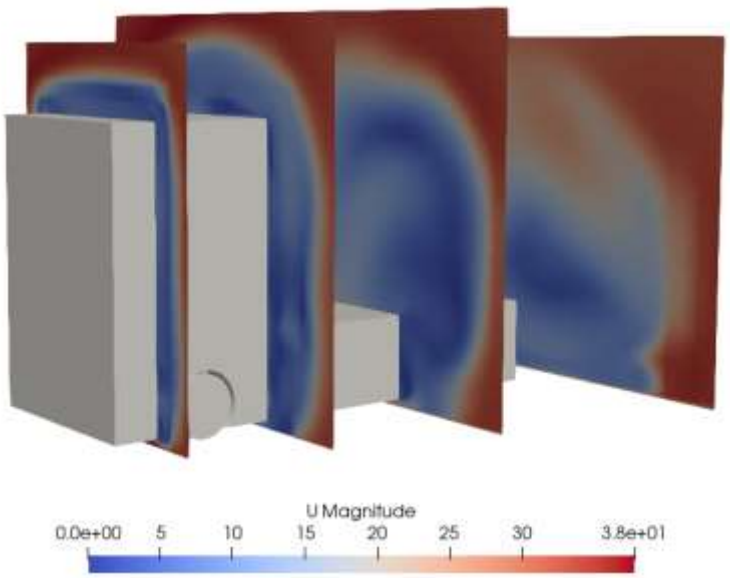


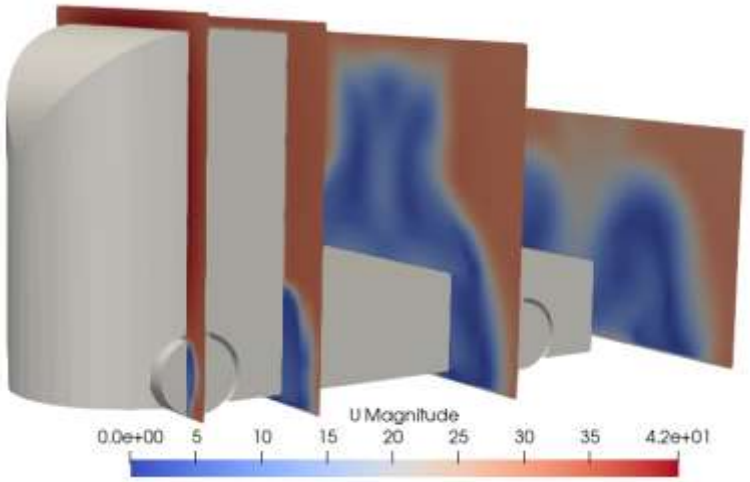


IMPROVEMENT 2:

ATTACHED FLOW OVER THE WHOLE SURFACE, NO SEPARATION ON SIDE EDGES TOO

CONVENTIONAL BASIC VS MODIFIED III

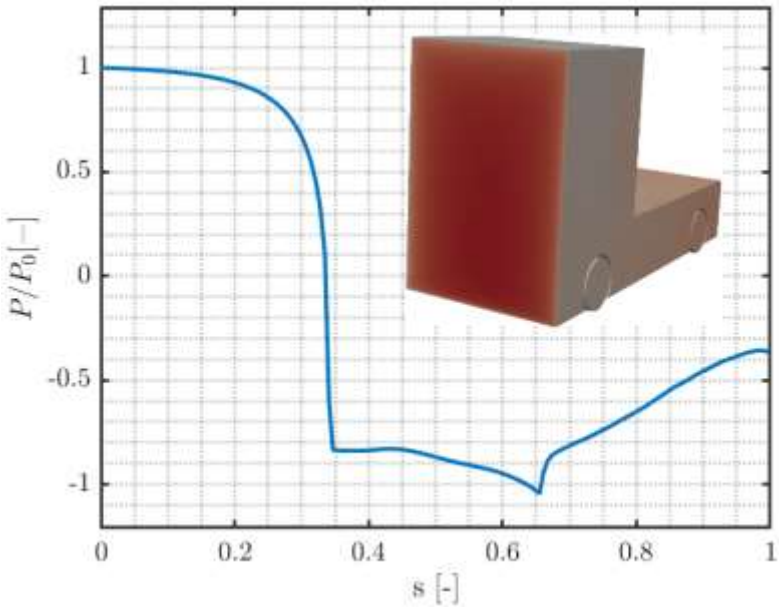


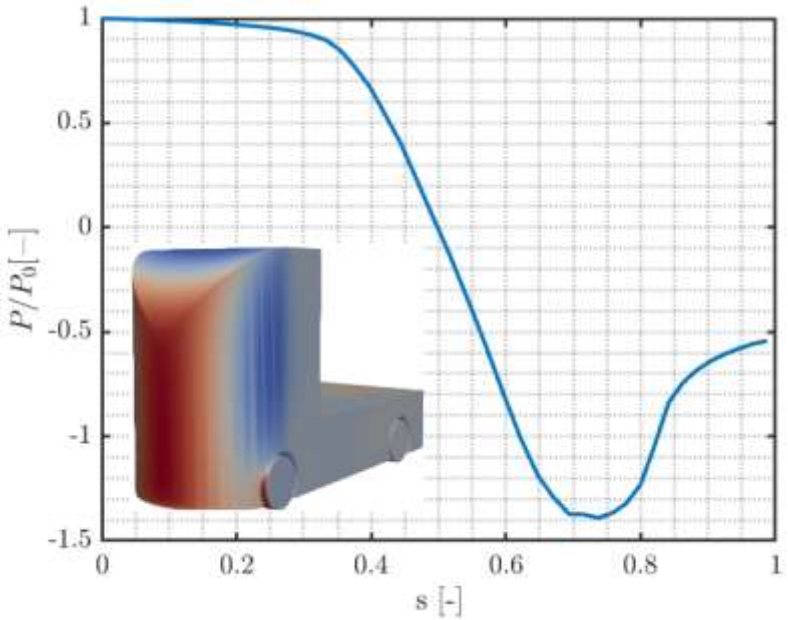


IMPROVEMENT 3:

OVERALL LIMITATION OF THE WAKE VOLUME

CONVENTIONAL BASIC VS MODIFIED IV





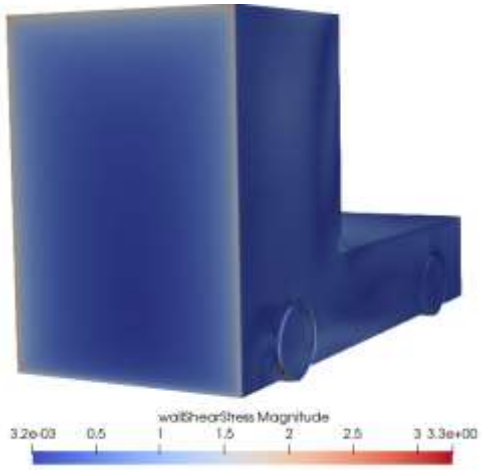
IMPROVEMENT 4:

SMOOTHER PRESSURE VARIATIONS AND ATTACHED EXPANSION

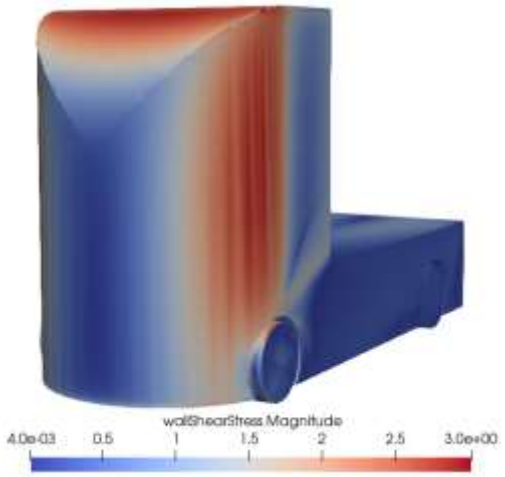
CONVENTIONAL BASIC VS MODIFIED V

	Conventional	*Conventional Modif*
CD	1.09	0.44

>60% IMPROVEMENT



CD viscous contribution = 0%



CD viscous contribution = 2%

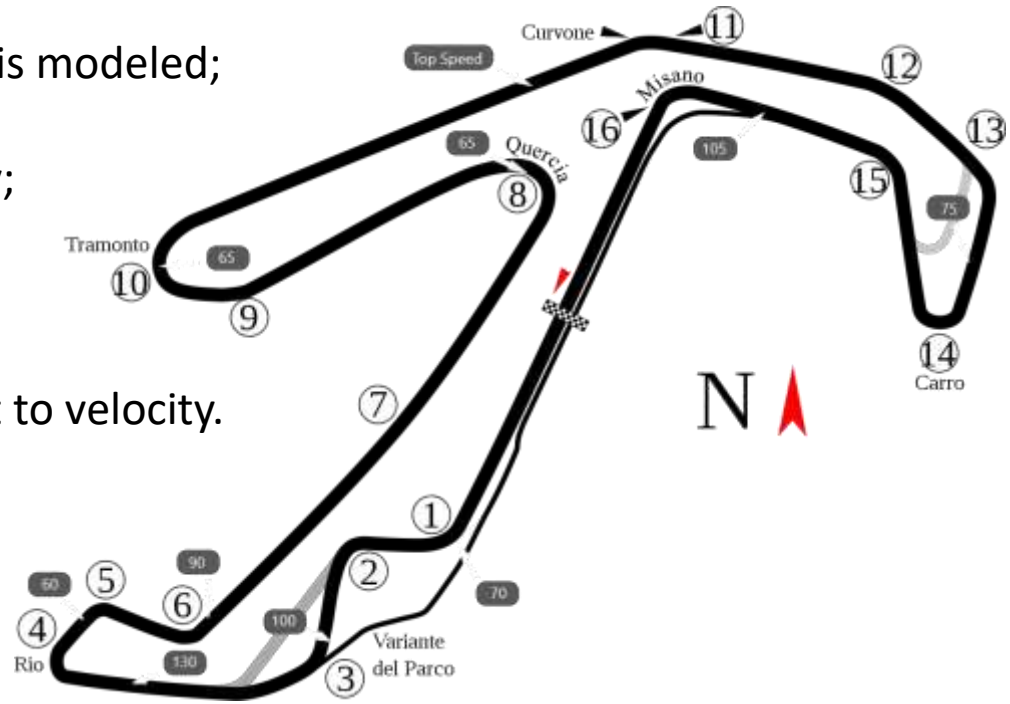
LAP TIME SIMULATION: the event

Every year Misano, Italy, hosts the first round of the season !!

LAP TIME SIMULATION: the model I

Every numerical approach is based on a series of hypothesis which drive the code design, here are the ones implemented in our code:

- No down-force development, only drag is modeled;
- Constancy of CD with respect to velocity;
- Neglection of tyres rolling resistance;
- Constancy of engine power with respect to velocity.



LAP TIME SIMULATION: the model II

PHYSICAL APPROACH:

Newton's second law with 2 contributions:

- power delivered by the engine;
- aerodynamic drag.

$$m\frac{dv}{dt} = \frac{P}{|v|} - \frac{1}{2}\rho v^2 A C_D$$

NUMERICAL APPROACH:

Finite Differences (FD) scheme:

$$V^{k+1} = V^k + \frac{KP\Delta t}{m}\frac{1}{V^k} - \frac{\frac{1}{2}\rho A C_d \Delta t}{m}V^{k2}$$

$$\Delta t = 0.0001 \text{ s}$$

LAP TIME SIMULATION: the results I

	Time
Conventional Modified	2:14:054
Tesla Semi	2:14:171
Racing	2:16:724
Conventional	2:19:773

>4% IMPROVEMENT IN THE TIME LAP BETWEEN BASIC AND CONVENTIONAL CONFIGURATIONS

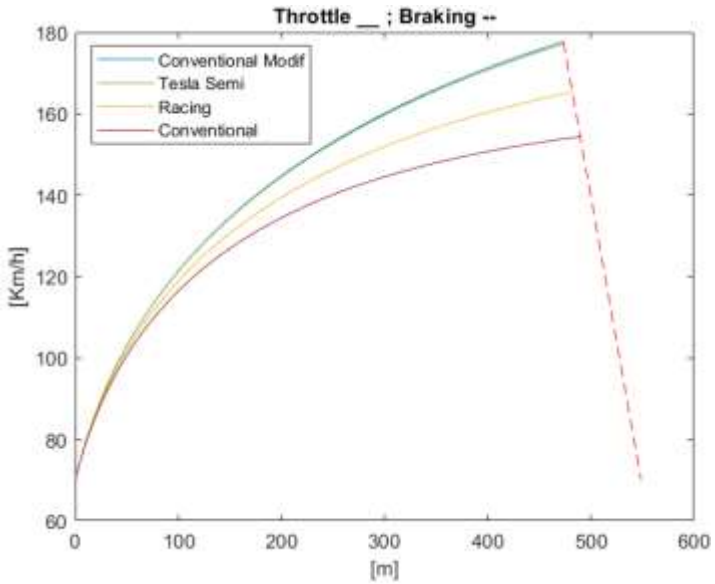
DRIVER	NAT	TEAM	TRUCK	TIME	LAPS
KISS NORBERT	HUN	REVESZ RACING (HUN)	MAN	2:03.732	5
HAHN JOCHEN	DEU	JOCHEN HAHN (DEU)	IVECO	2:05.009	5
HALM STEPHANIE	DEU	STEPHANIE HALM (DEU)	IVECO	2:05.081	5
ALBACETE ANTONIO	ESP	TEAM T SPORT BERNAU (AUT)	MAN	2:05.545	5
KURSIM ANDRE	DEU	ANDRE KURSIM (DEU)	IVECO	2:05.895	5
RODRIGUES JOSE EDUARDO	PRT	JOSE EDUARDO RODRIGUES (PRT)	MAN	2:06.235	4
FAAS STEFFEN	DEU	TANKPOOL 24 RACING (DEU)	SCANIA	2:06.326	5
TAYLOR MARK	GBR	MARK TAYLOR (GBR)	MAN	2:07.001	5
ANDRE JONATHAN	FRA	JONATHAN ANDRE (FRA)	MAN	2:07.499	4
RECUENCO LUIS	ESP	LUIS RECUENCO (ESP)	IVECO	2:07.945	3

Same order of magnitude compared to final standings of qualifying session of 2023 event

LAP TIME SIMULATION: the results II

	V [km/hr]
Conventional Modified	177.75
Tesla Semi	177.20
Racing	166.04
Conventional	154.37

>15% IMPROVEMENT IN MAX VELOCITY BETWEEN BASIC AND CONVENTIONAL CONFIGURATIONS



Max velocity cannot exceed 160 km/hr

CONCLUSIONS

- Preliminary analysis shows that streamlined geometry without roof spoiler provides the best performances in terms of drag
- 60% Cd reduction after implementing the inferred modifications
- 4% improvement in lap performance
- 15% increase in maximum velocity


THANK
YOU