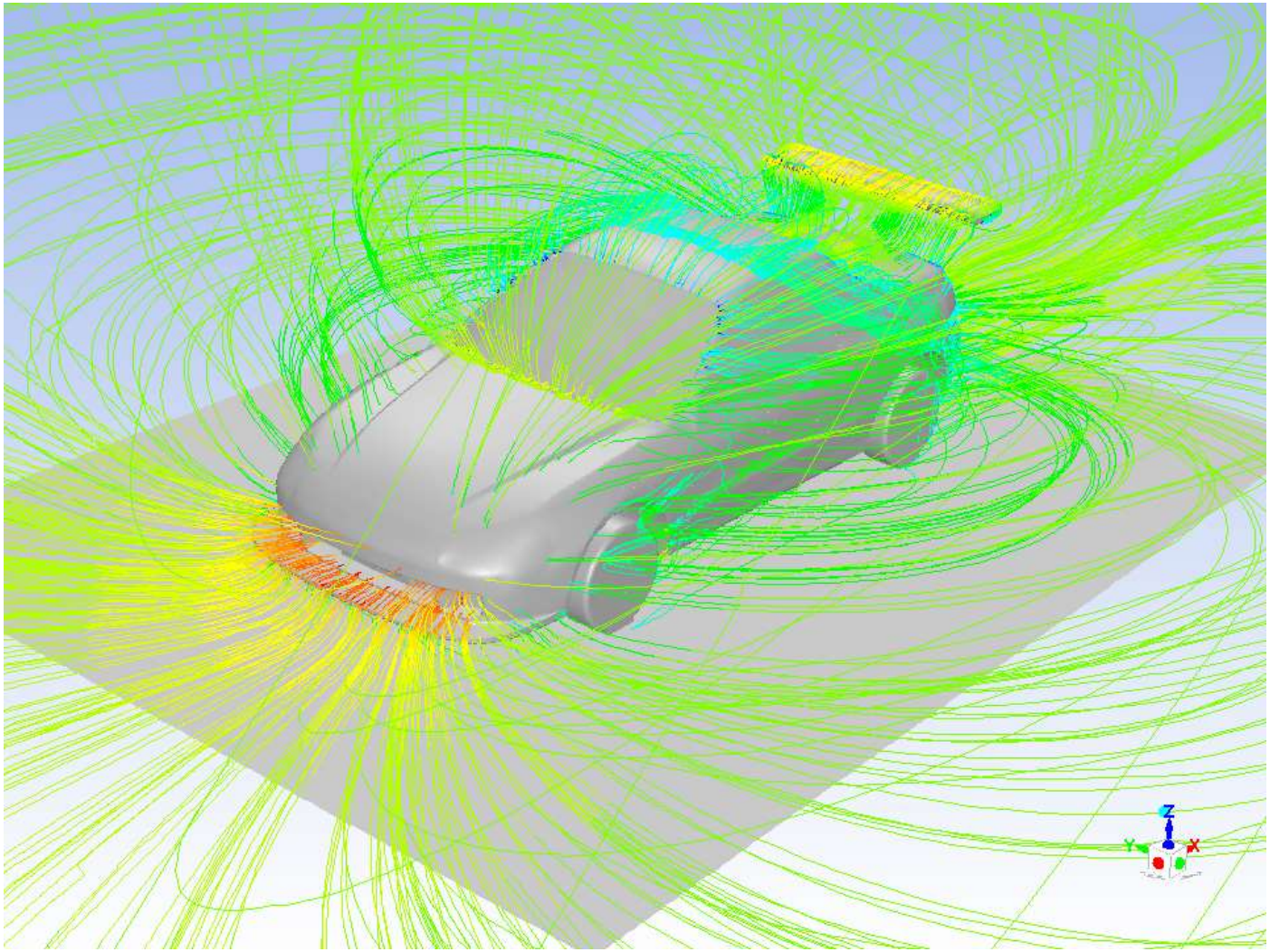
Ground vehicle dynamics in the presence of unsteady aerodynamics loads



Jakub Broniszewski

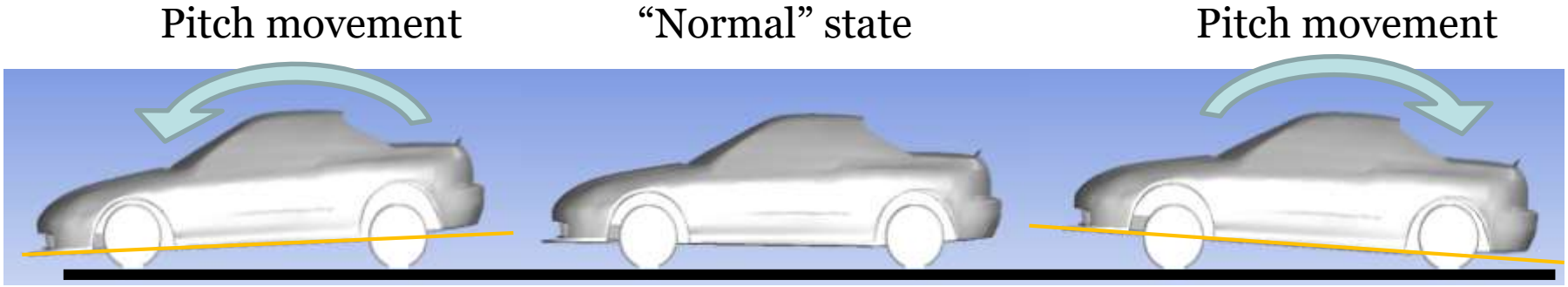
Janusz Piechna

Outline

1. Motivation
2. Methodology
3. Results
4. Plans for future work
5. Questions

Main Reason for Need of FSI for Car Dynamics Analysis

- During makeovers the car can experience vertical oscillation
- This movement is conjugated with change in pressure distribution
- The phenomenon is dynamic
- FSI approach is required. In this work we will be focused on vertical oscillation and how it will affect aero forces.



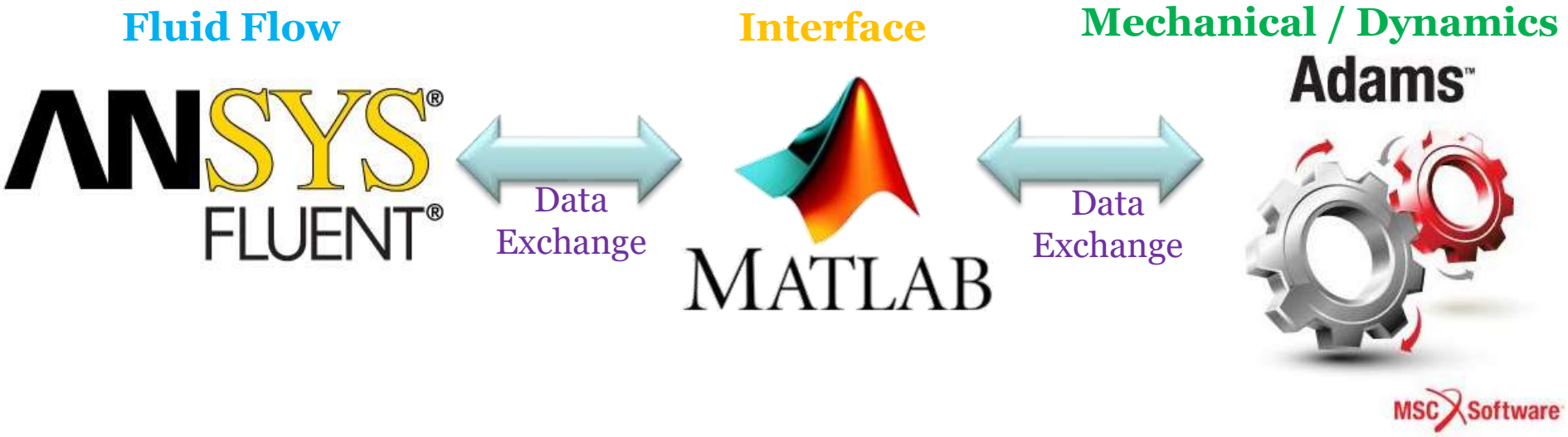
Ultimately, we would like to be able to control active aerodynamics to damp car oscillation.

Main reason for need of FSI for car dynamics analysis

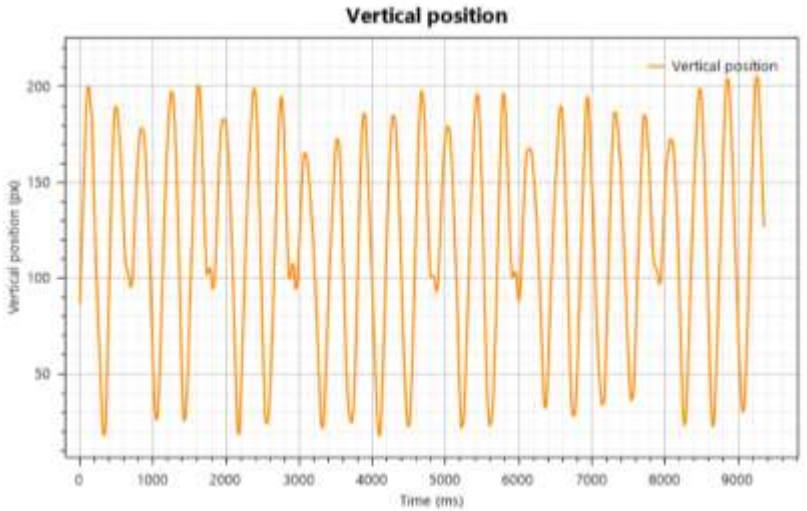
Extreme example of undesirable car behavior

Methodology and Tools Ecosystem

- Co-simulation approach (FSI)
- Bi-directional data exchange between Fluent and MCS.Adams
- Matlab acting as an interface and control system

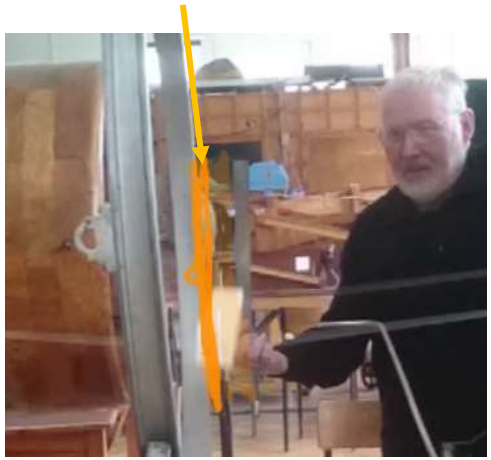


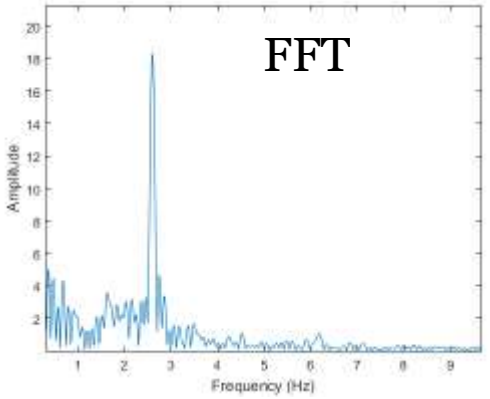
Methodology Validation – Experiment



Variable	Value
Air velocity	~4 m/s
Cylinder dimension	50x50x540
Frequency	~2.6Hz
Amplitude	~200mm

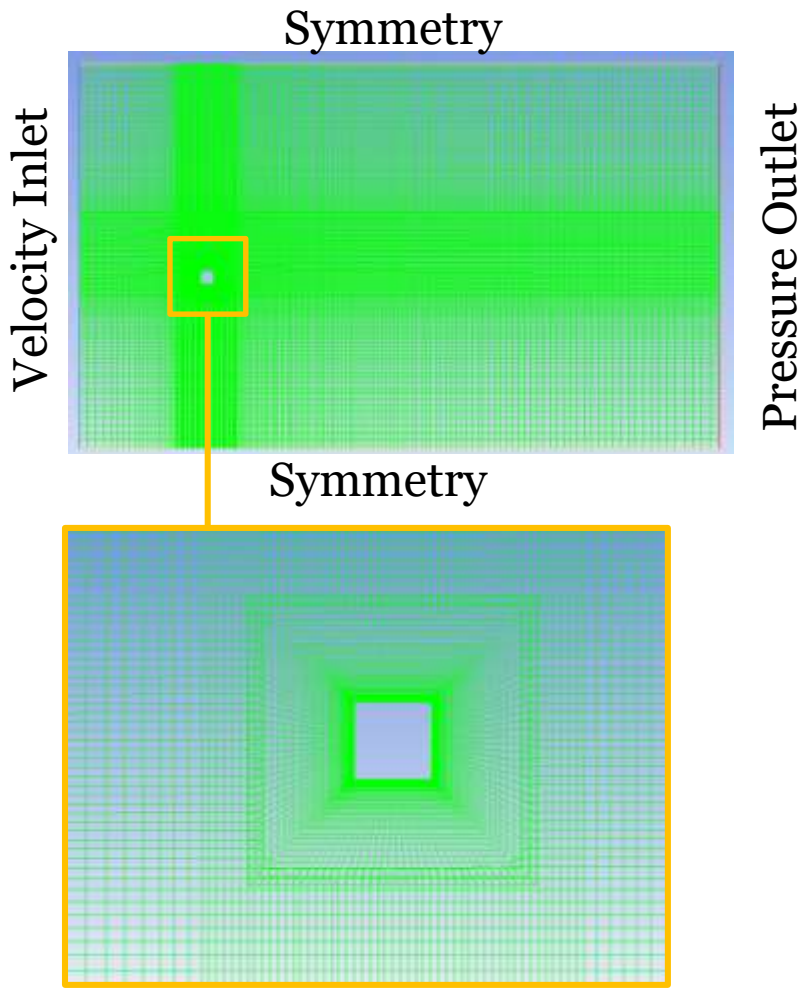
Trajectory



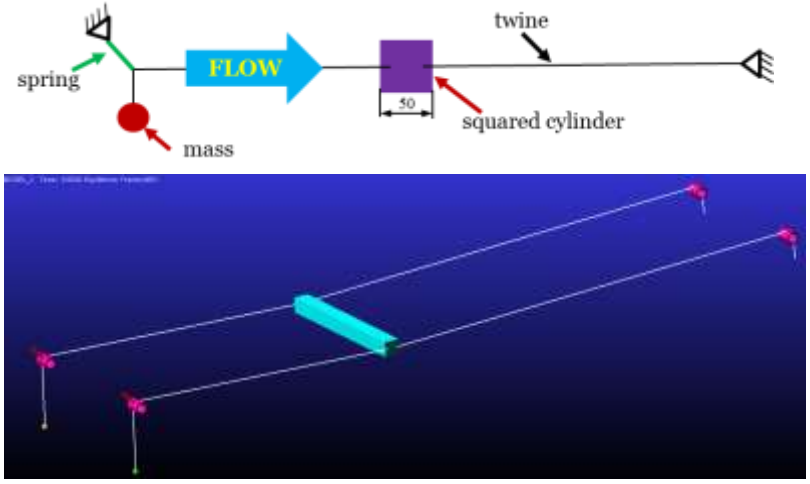


Methodology Validation – Numerical Model

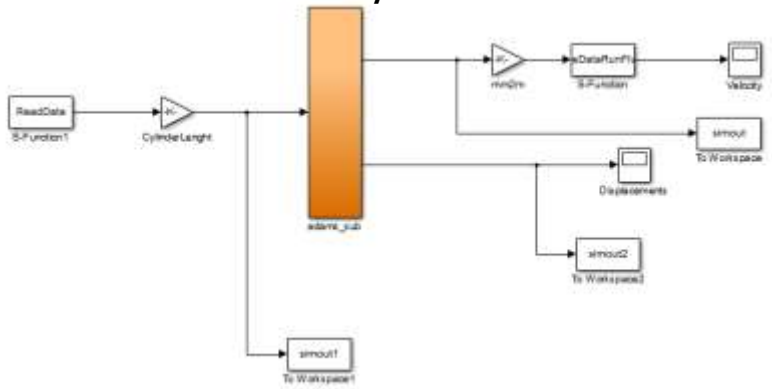
Fluent mesh and BCs



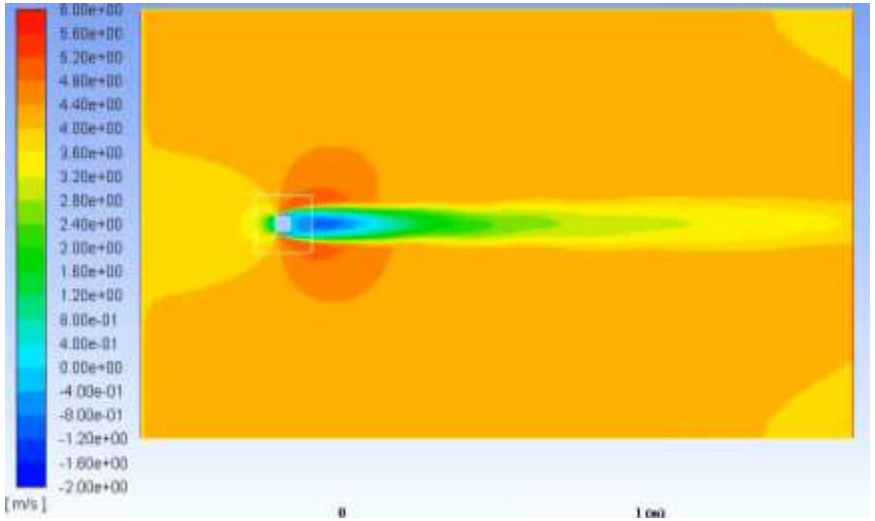
Adams Model

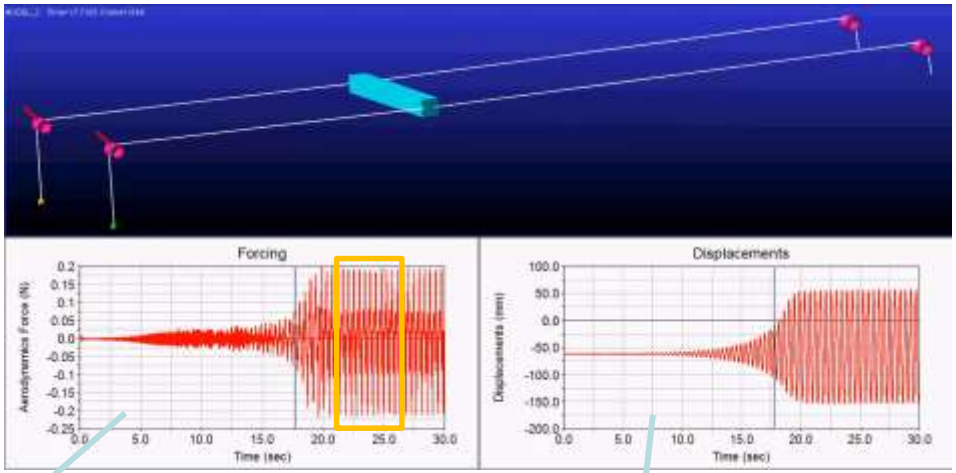


Matlab/Simulink

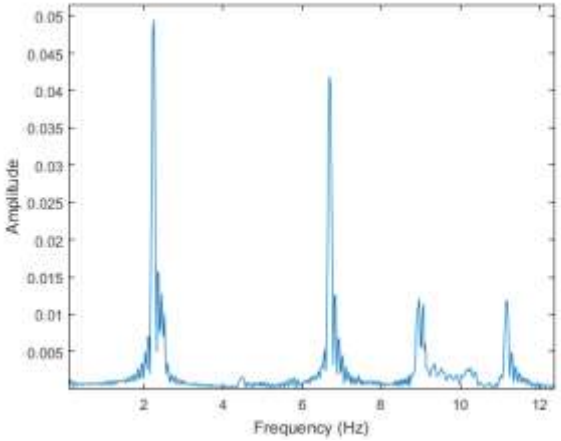


Methodology Validation – Numerical Results

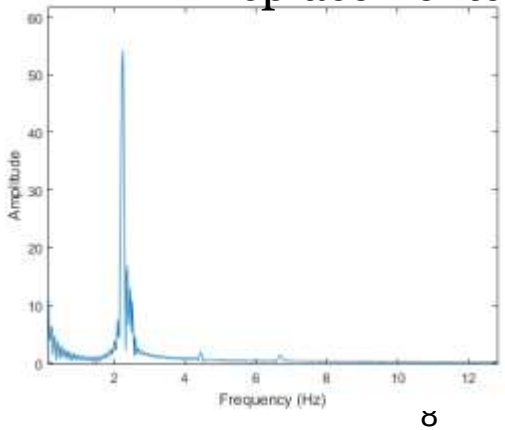




FFT – Aerodynamics Forces

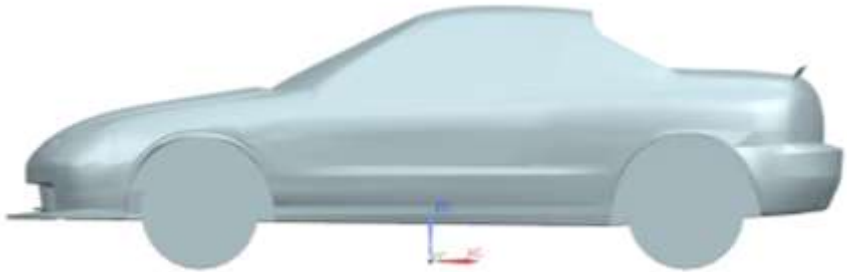


FFT – Displacements

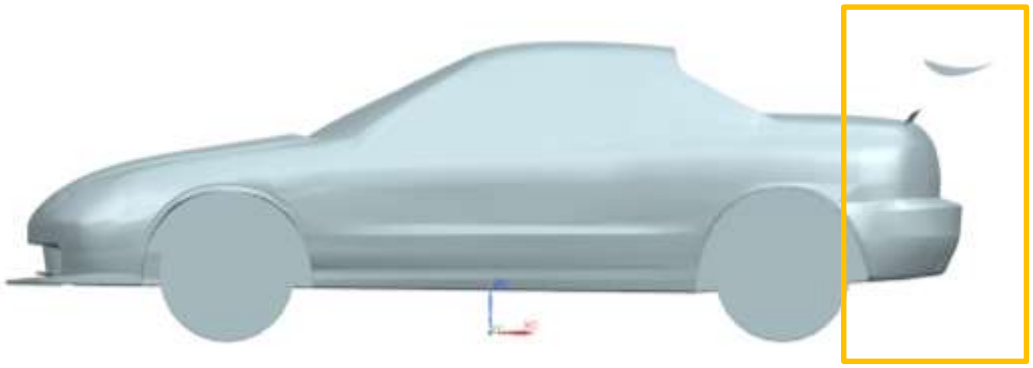


Analyzed Configurations

Base Configuration



Configuration with movable airfoil



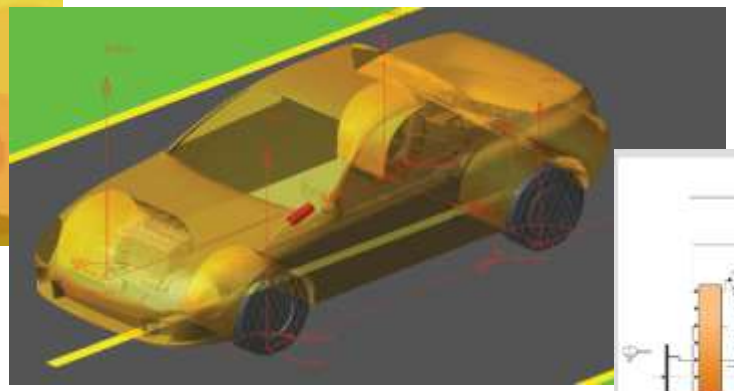
Starting position

During movement

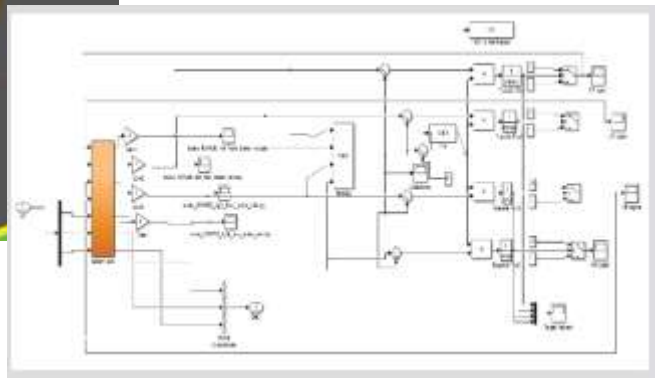
Full Car Dynamics – Braking Maneuver

- CFD model build in ANSYS Fluent (half car)
- Full car dynamic model build in MSC.ADAMS/Car
- Interface build in Matlab/Simulink

FLUENT
Flow Analysis



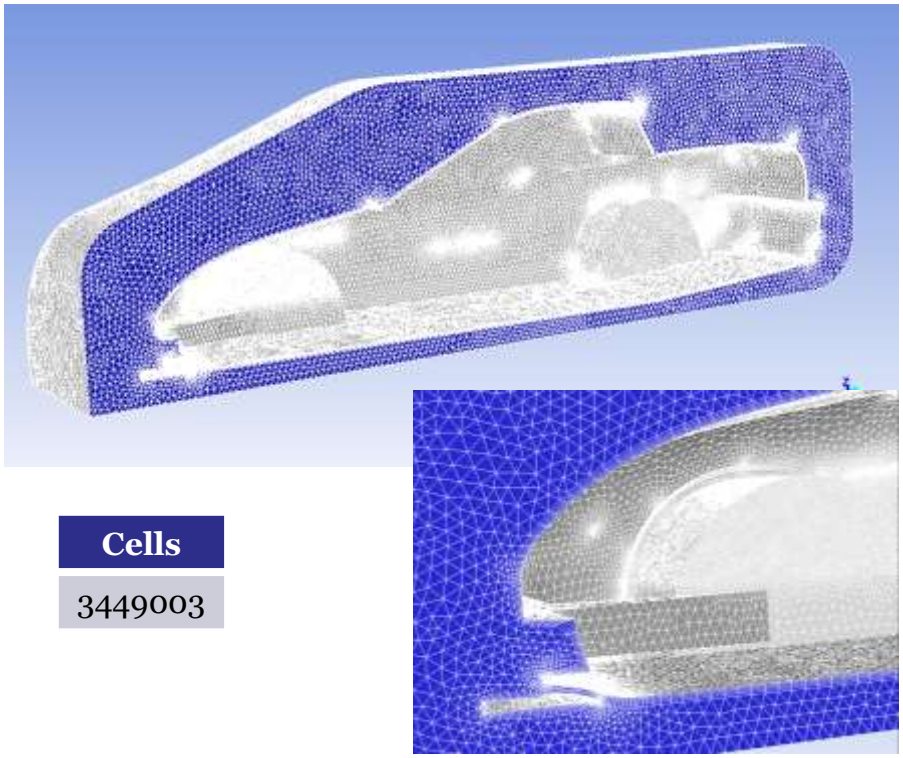
MSC.ADAMS/Car
Car Body Dynamics



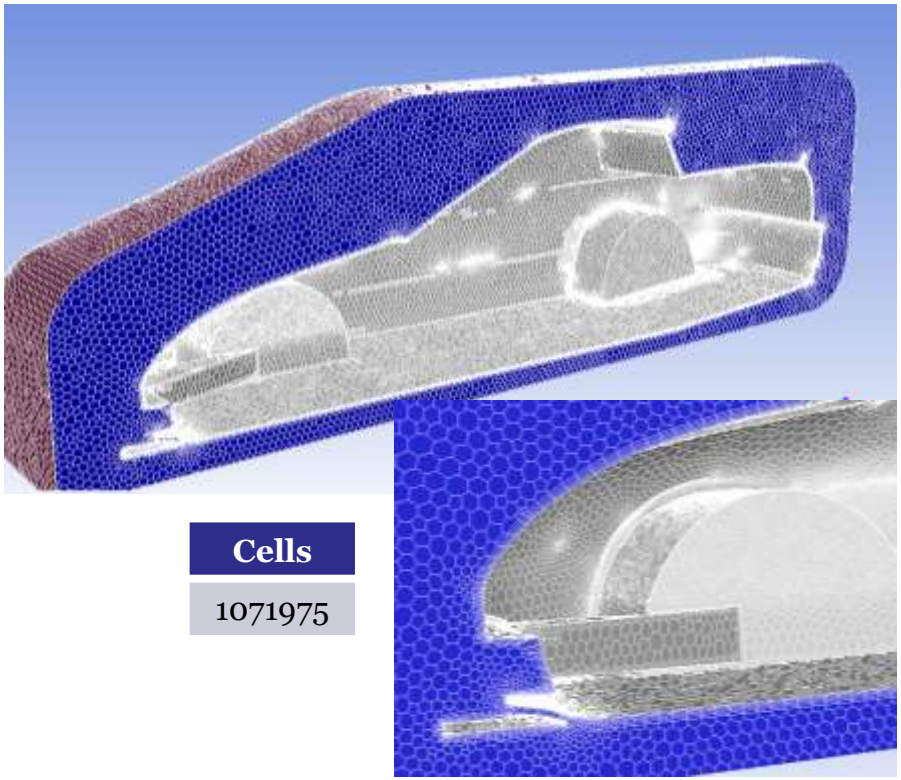
Matlab/Sumulink
interface & control system

Main Technics Used in the Analysis

Flow Model - Tetrahedral Mesh Converted to Polyhedral



Cells
3449003

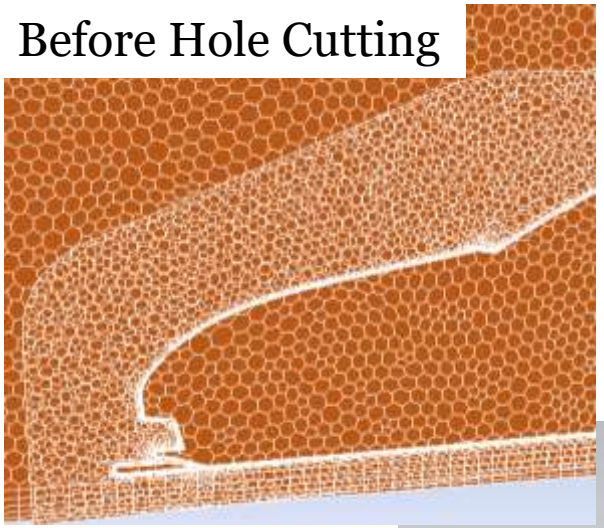


Cells
1071975

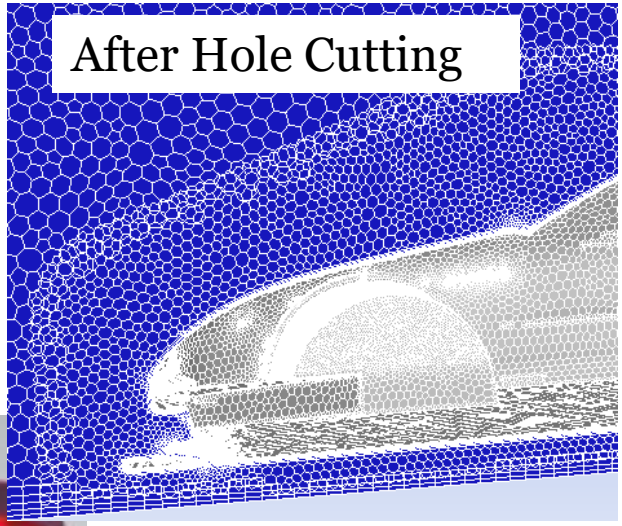
Main Technics Used in the Analysis

Flow Model - Overset Mesh

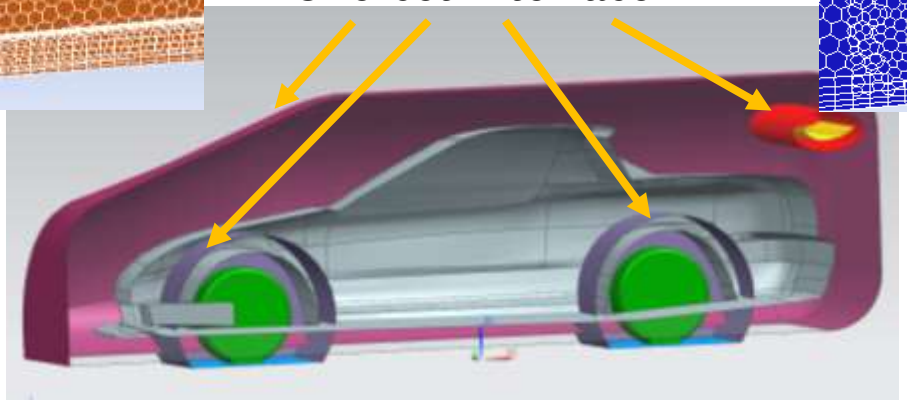
Before Hole Cutting



After Hole Cutting



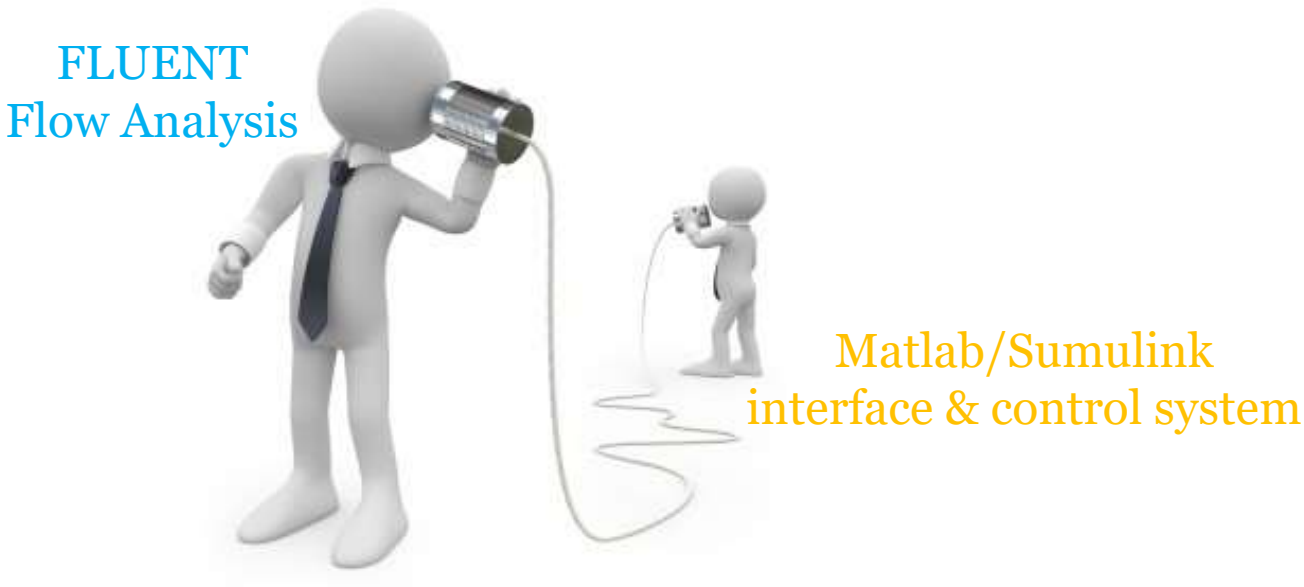
Overset interface



Main Technics Used in the Analysis

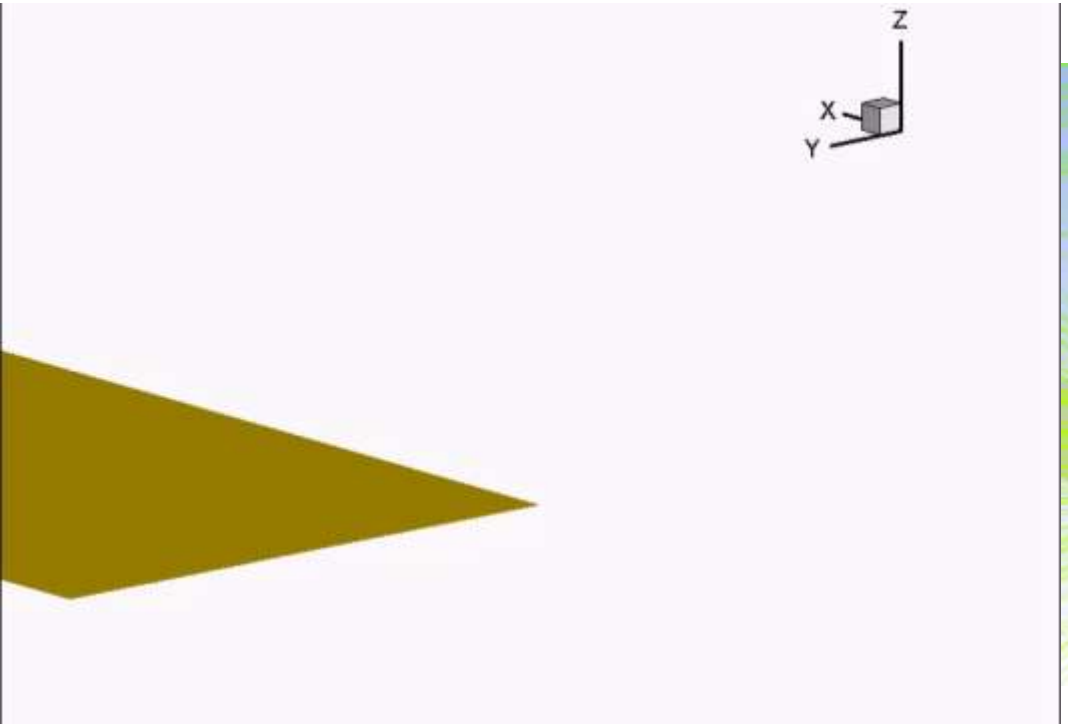
Flow Software / Interface – Fluent "as-a-server"

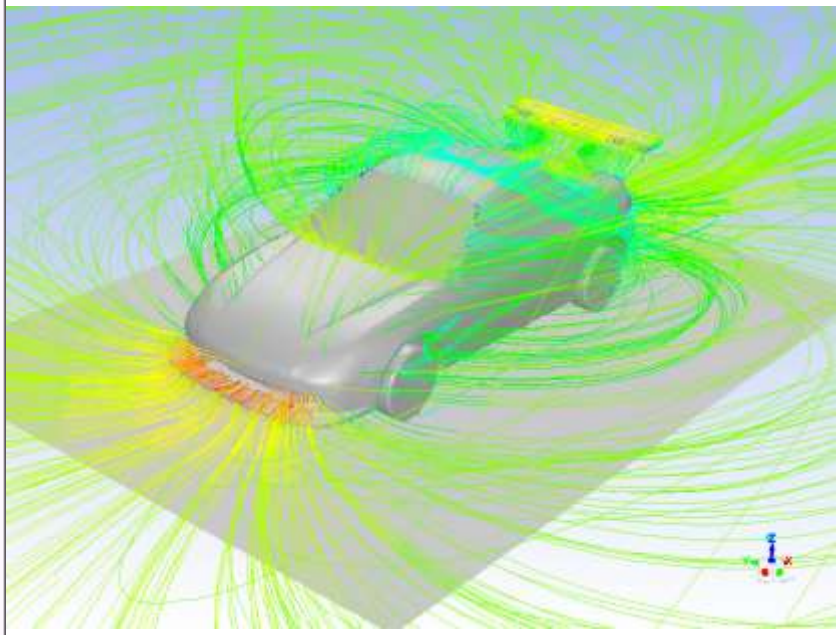
Pros	Cons
Easy to connect with external software	Additional Software
Different platforms and locations	
Continues journaling	



Main Technics Used in the Analysis

Moving Domain

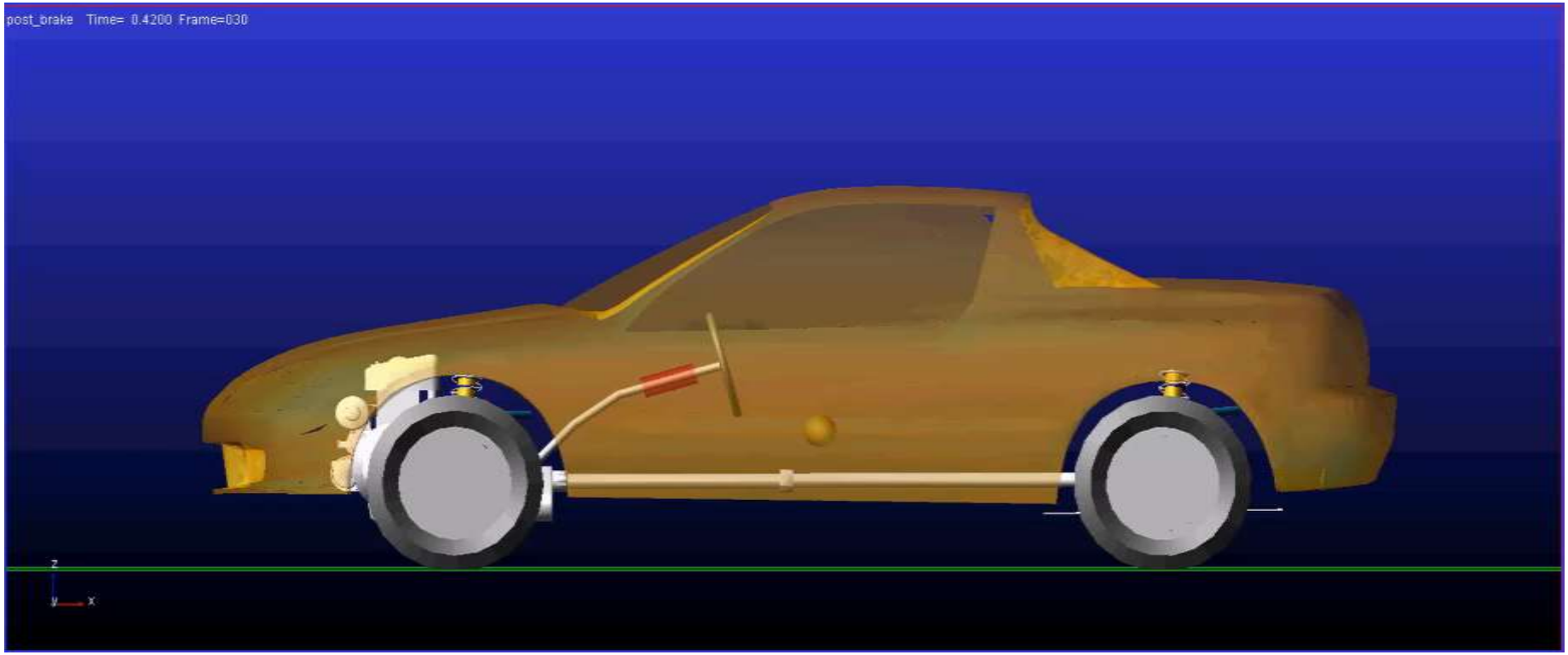




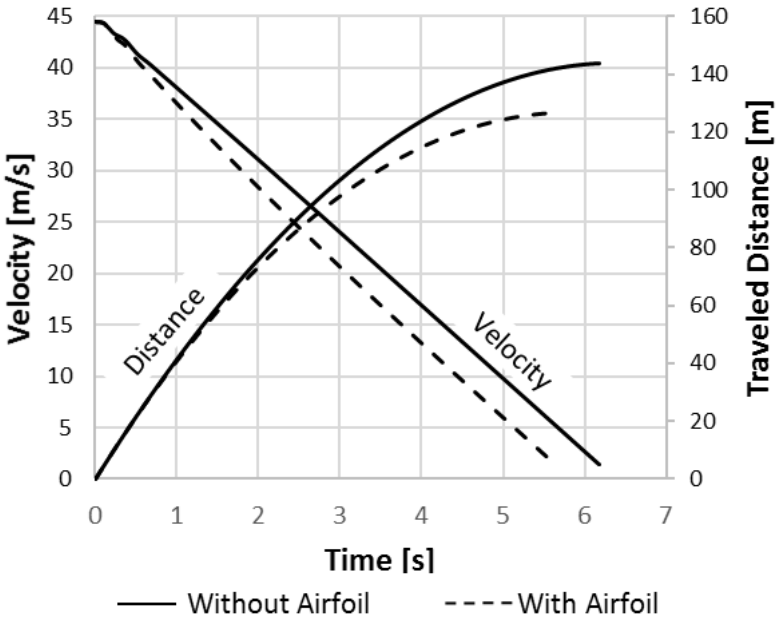
We have different reference frame

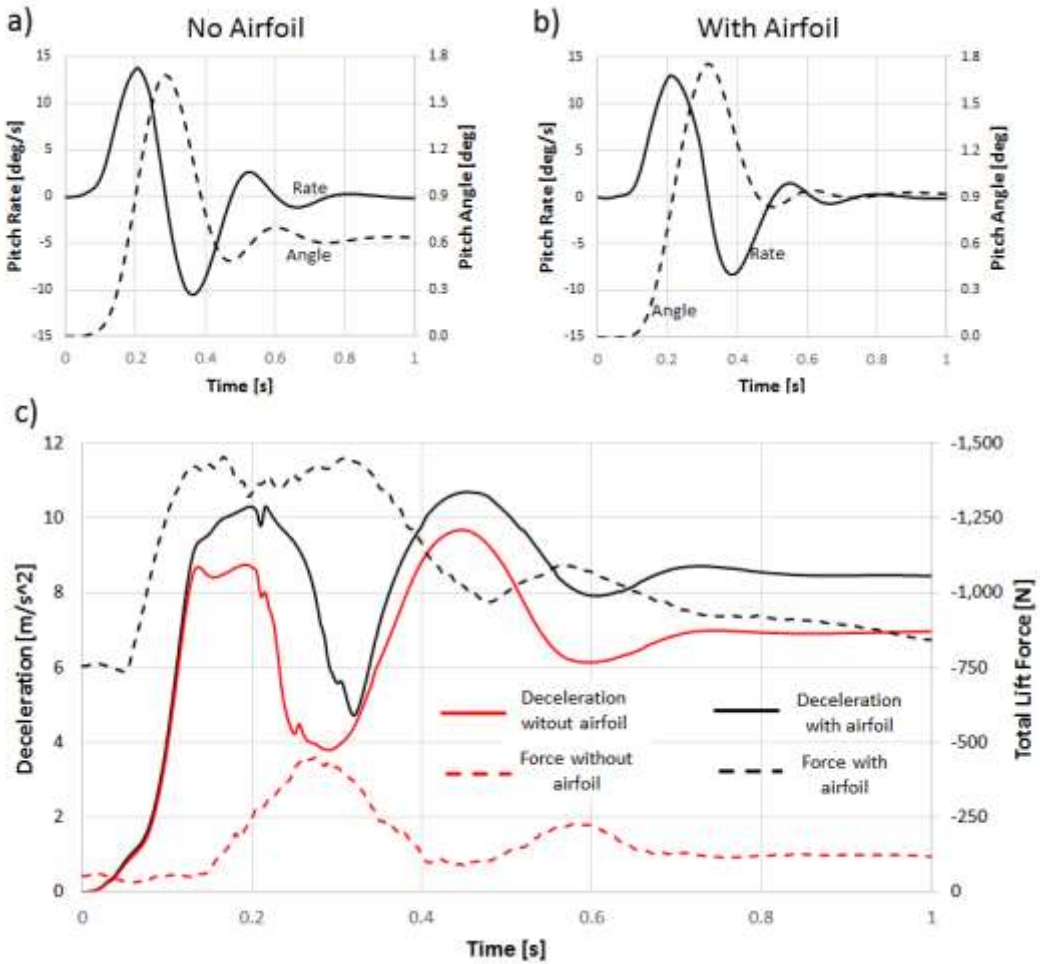
Results

Car behavior

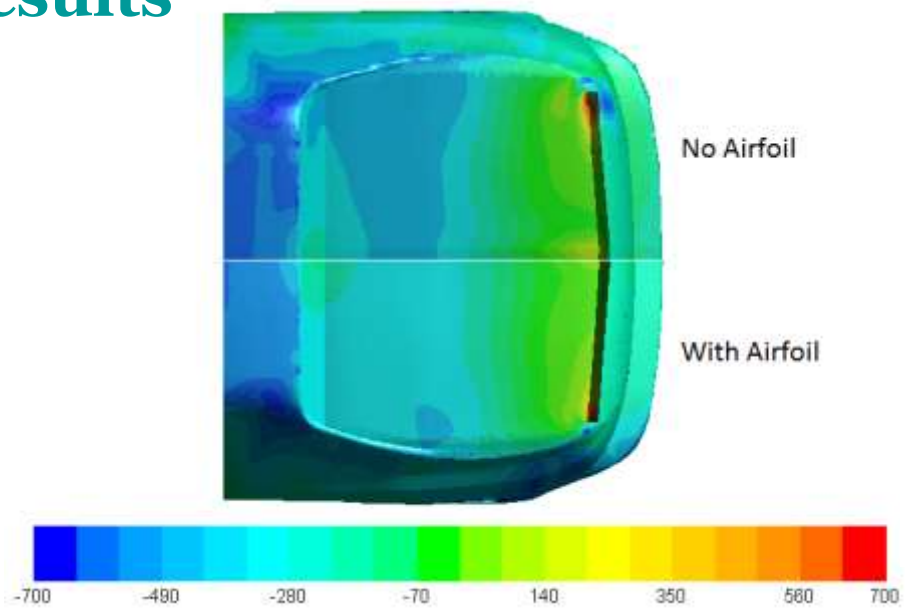


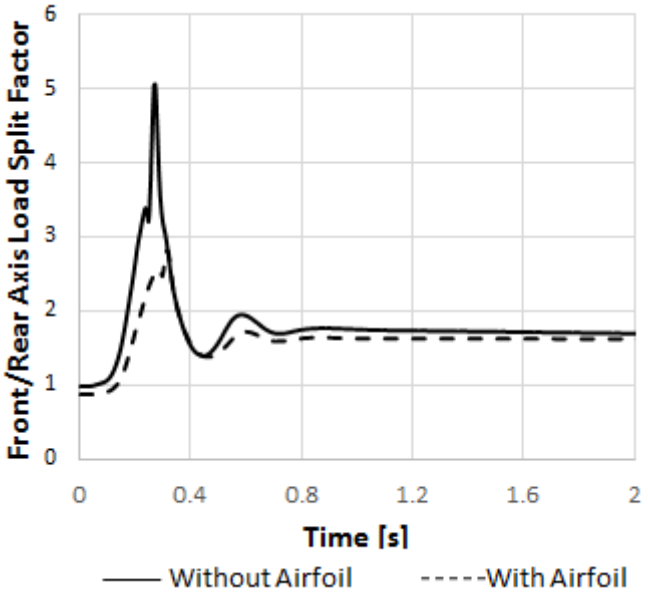
Results

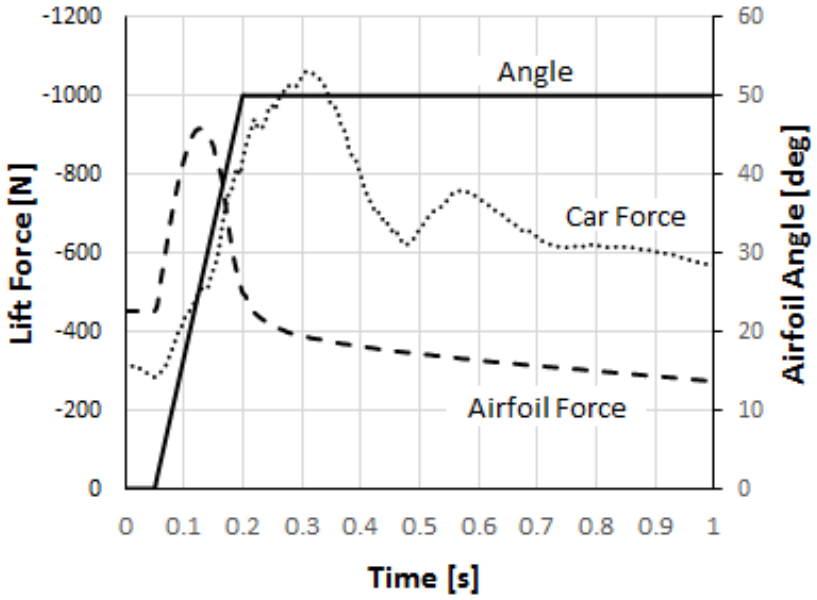

Velocity [m/s]
Traveled Distance [m]
Time [s]
Distance
Velocity
Without Airfoil
With Airfoil

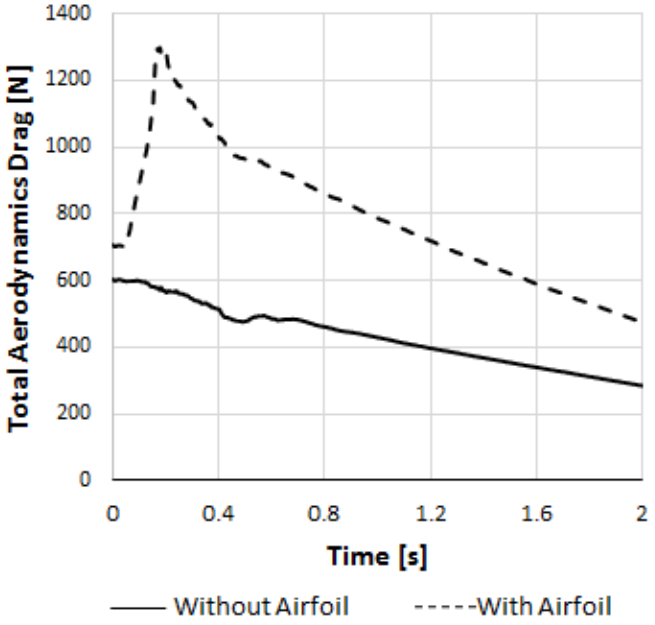

a)
No Airfoil
b)
With Airfoil
Pitch Rate [deg/s]
Pitch Angle [deg]
Rate
Angle
Time [s]
c)
Deceleration [m/s^2]
Total Lift Force [N]
Deceleration witout airfoil
Deceleration with airfoil
Force without airfoil
Force with airfoil
Time [s]

Results

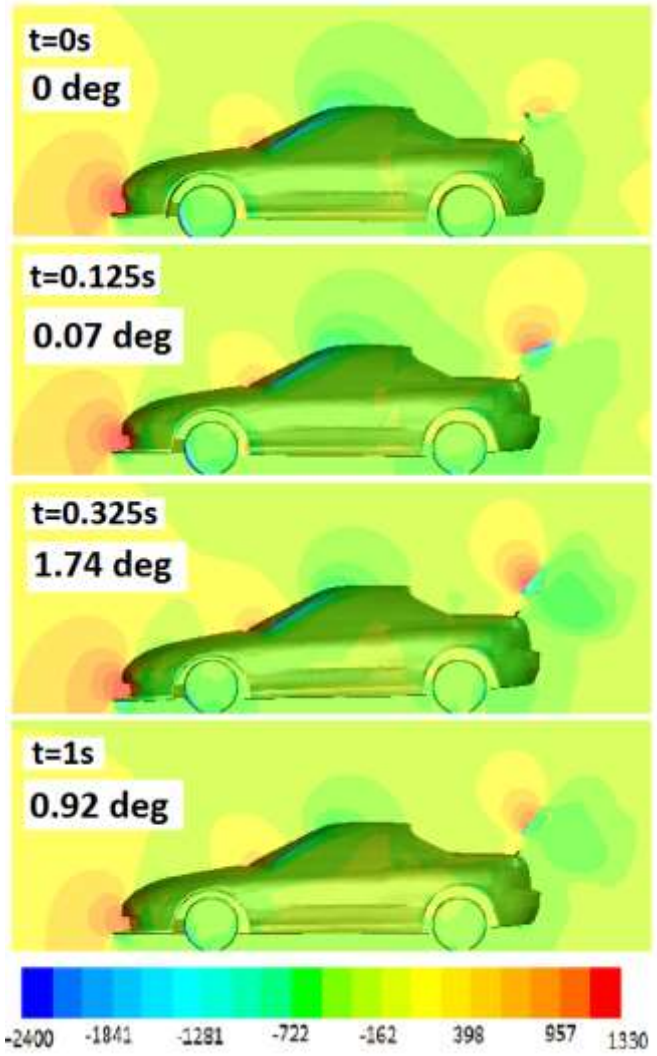

No Airfoil
With Airfoil
-700
-490
-280
-70
140
350
560
700

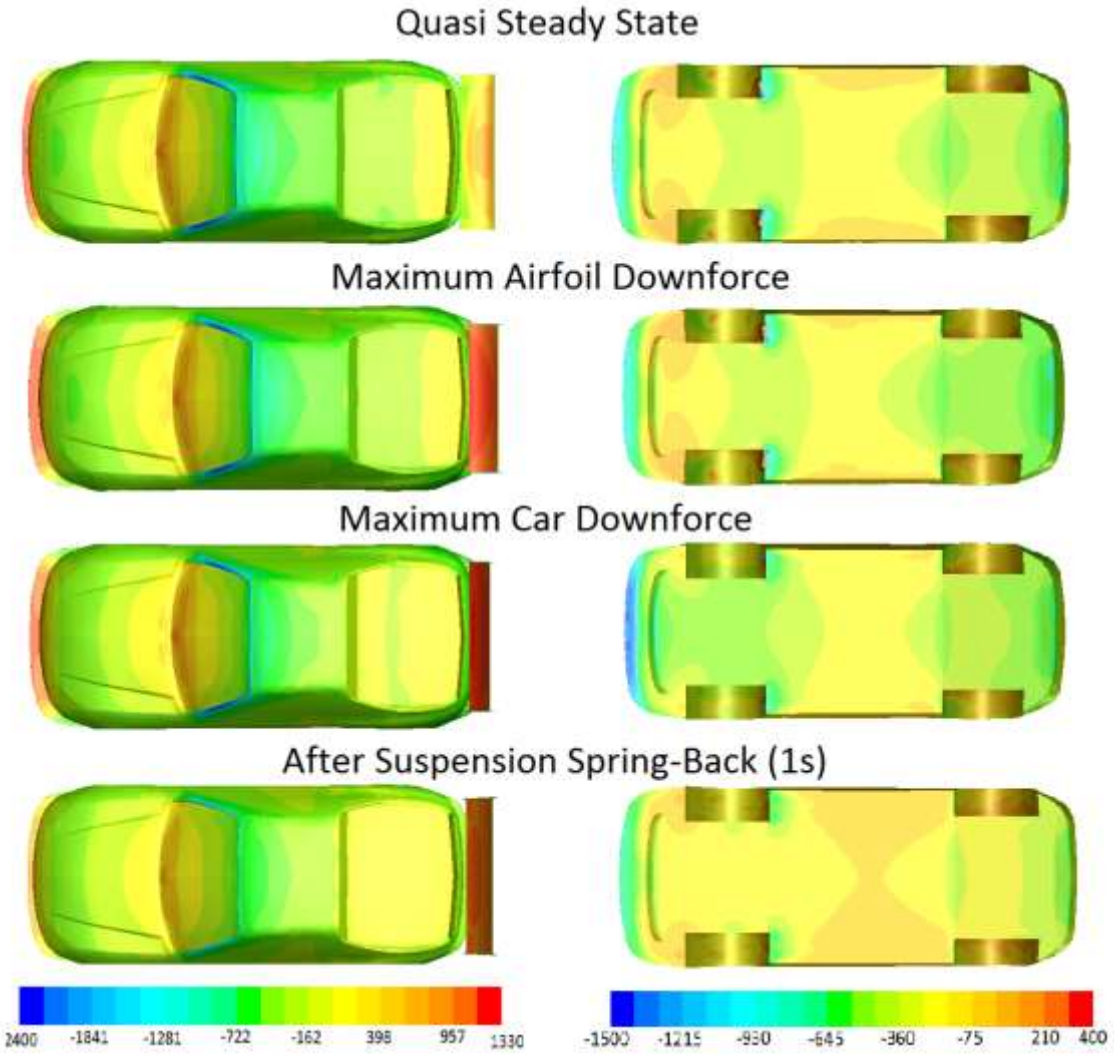

Front/Rear Axis Load Split Factor
Time [s]
Without Airfoil
With Airfoil


Angle
Car Force
Airfoil Force
Lift Force [N]
Airfoil Angle [deg]
Time [s]

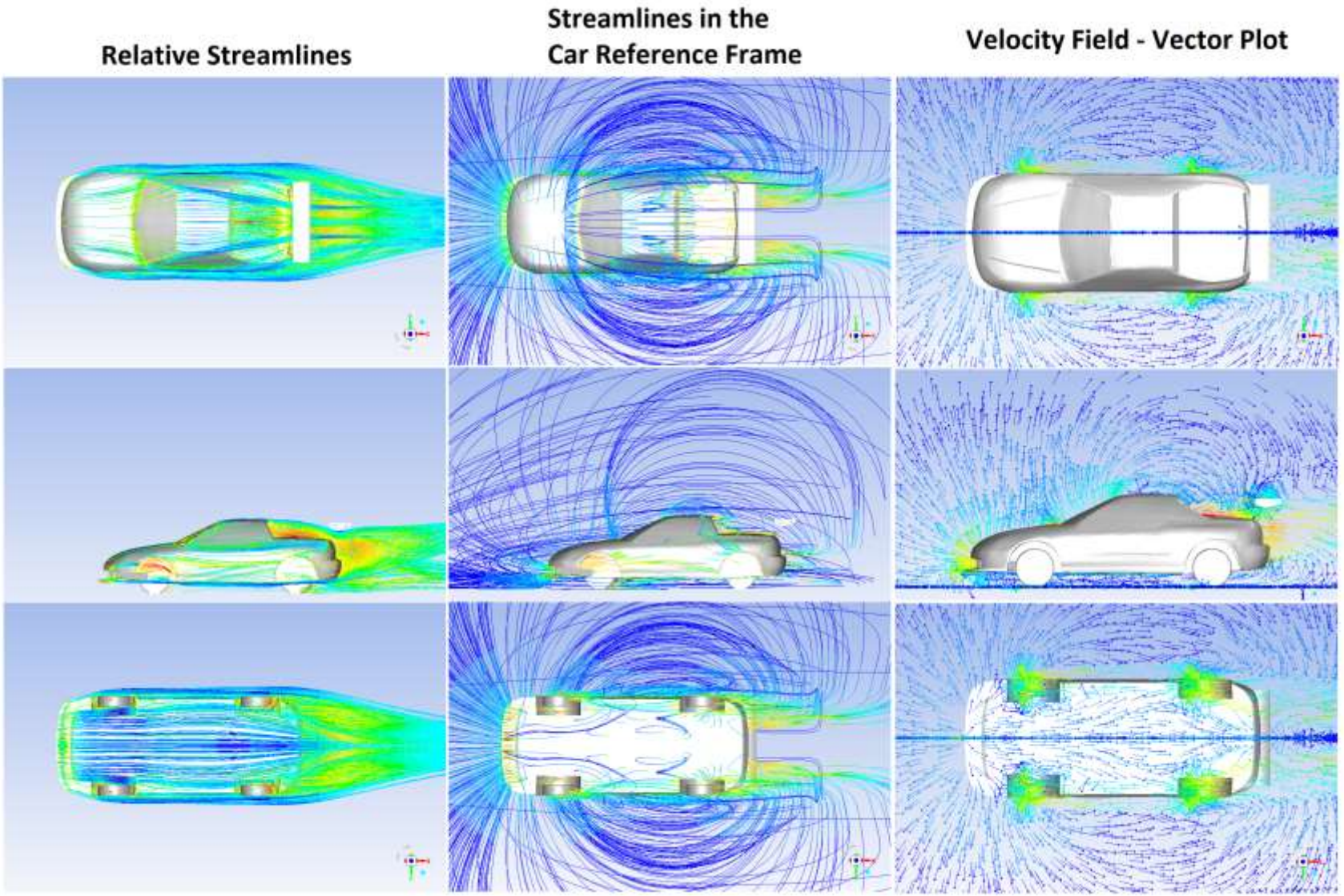

Total Aerodynamics Drag [N]
Time [s]
Without Airfoil
With Airfoil

Results


t=0s
0 deg
t=0.125s
0.07 deg
t=0.325s
1.74 deg
t=1s
0.92 deg
-2400
-1841
-1281
-722
-162
398
957
1330

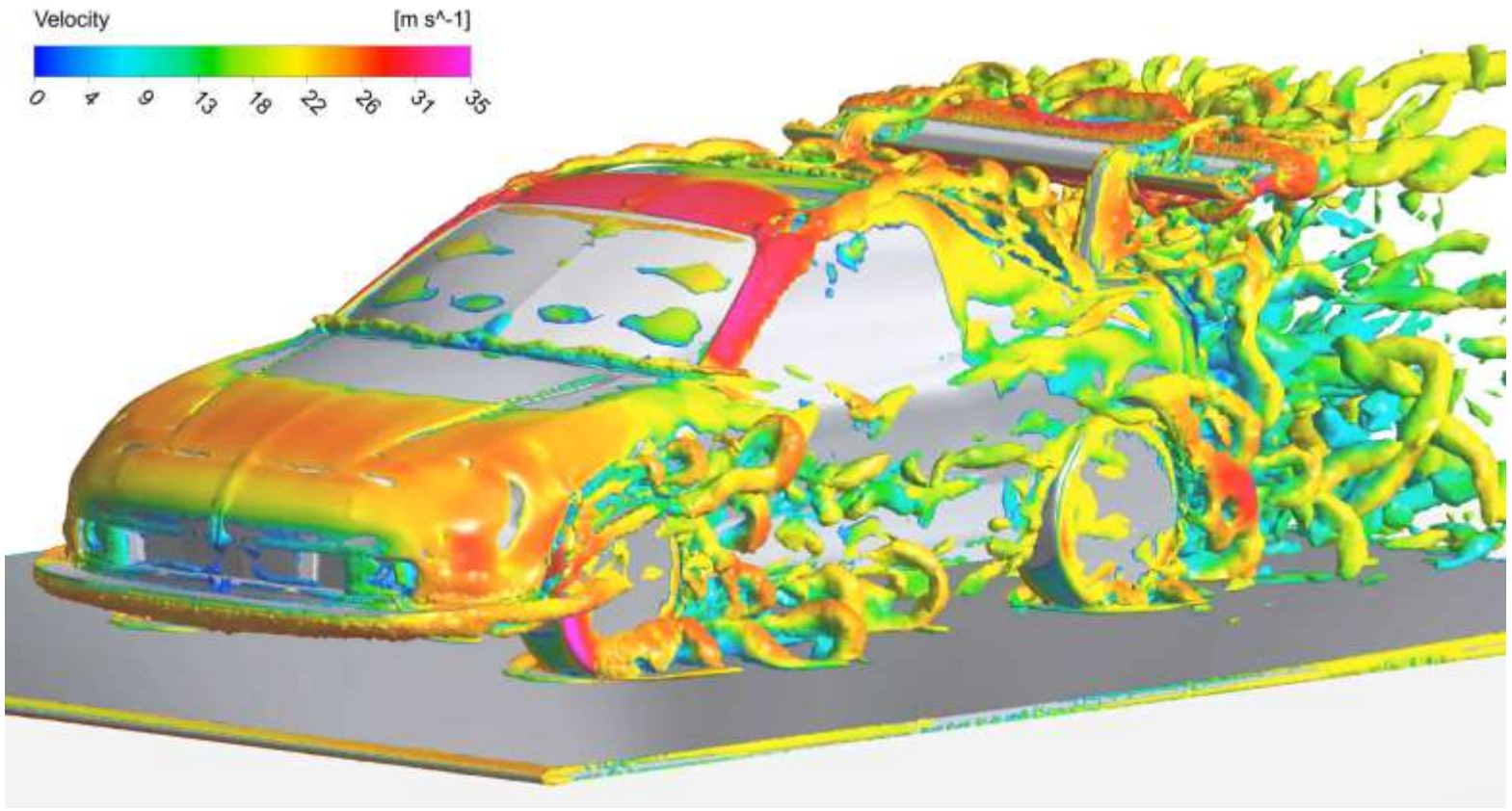

Quasi Steady State
Maximum Airfoil Downforce
Maximum Car Downforce
After Suspension Spring-Back (1s)
2400
-1841
-1281
-722
-162
398
957
1330
-1500
-1215
-930
-645
-360
-75
210
400

Results


Relative Streamlines
Streamlines in the Car Reference Frame
Velocity Field - Vector Plot

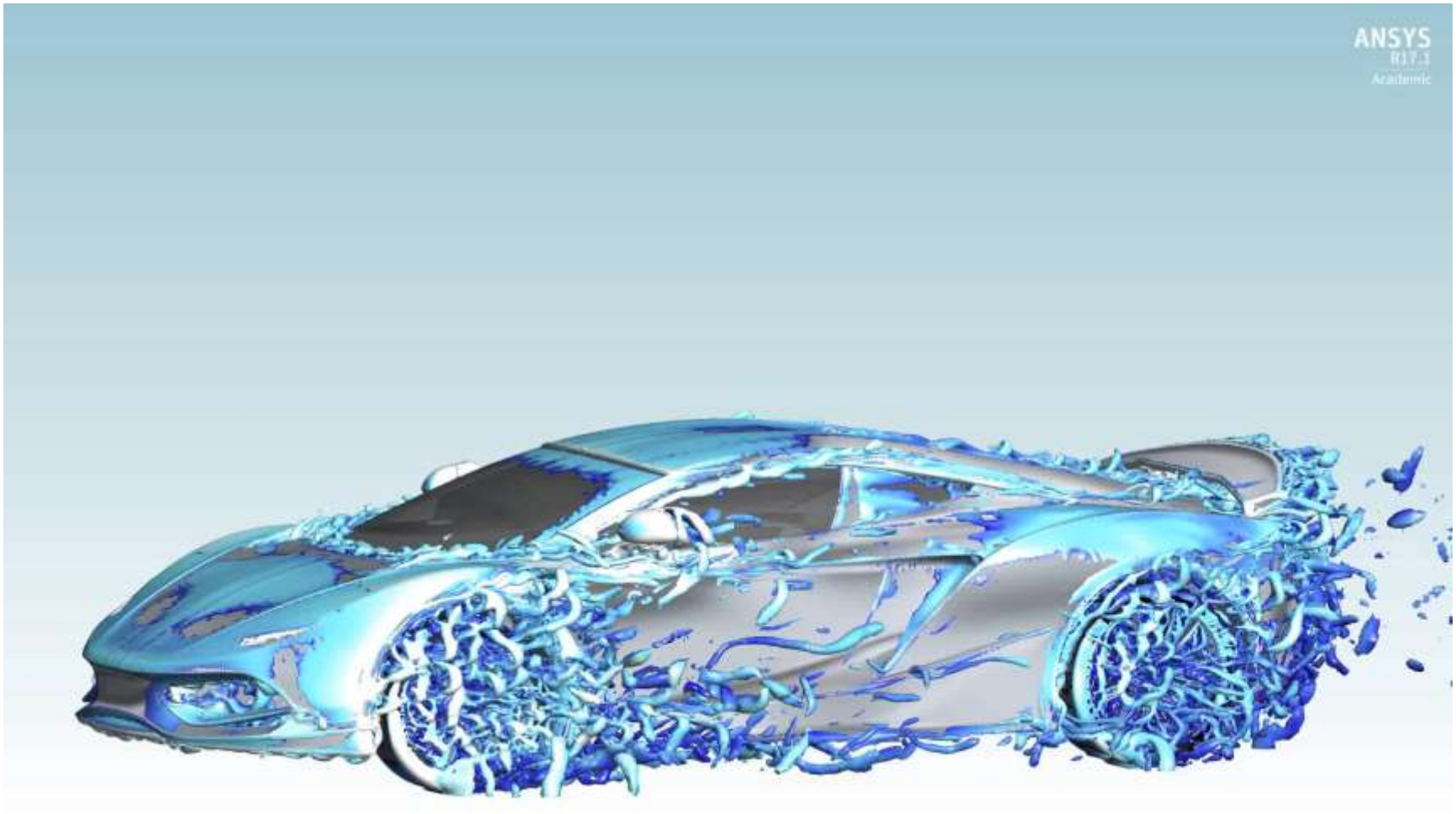
Preliminary Results

Flow Structure @ Constant Velocity



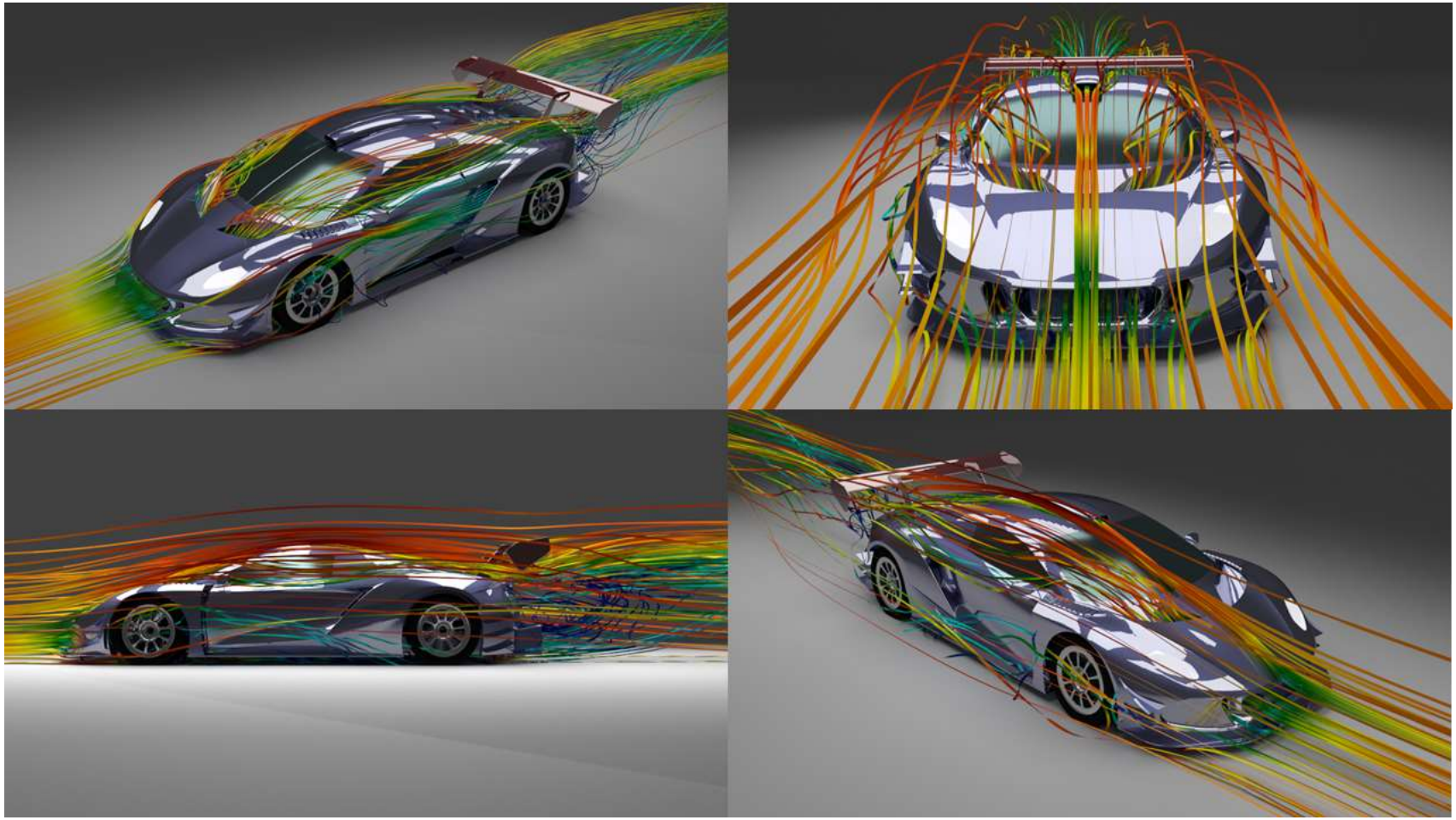
The analysis was performed by Krzysztof Kurec

The Ultimate Application



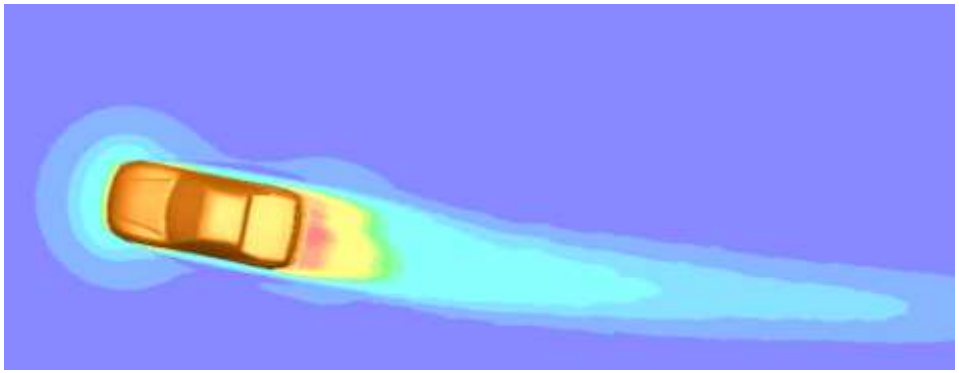
The analysis was performed by Krzysztof Kurec

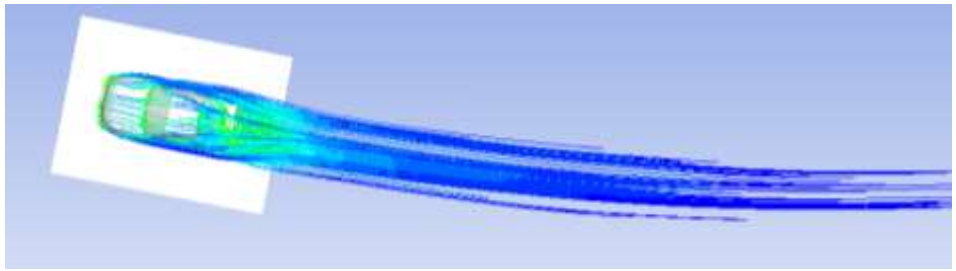
The Ultimate Application



Conclusions and Future Work

- Proposed methodology works as expected
- Validation against the test is crucial
- High speed unsteady aerodynamics effects are important





Thank You!!