

The bubble: a dedicated platform for car cabin air pollution measurements

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CREATEUR DE NOUVELLES MOBILITES



SUMMARY

- The context and the objective of the study
- The Airtight chamber for vehicle cabin air characterization (the bubble)
- Example of car cabin air characterization of a vehicle.
- Numerical investigation of the flow topology around measurement probe (CFD)
- Conclusion

CONTEXT AND OBJECTIVE

PhD Thesis: Definition of protocol for vehicle in-cabin air quality measurements
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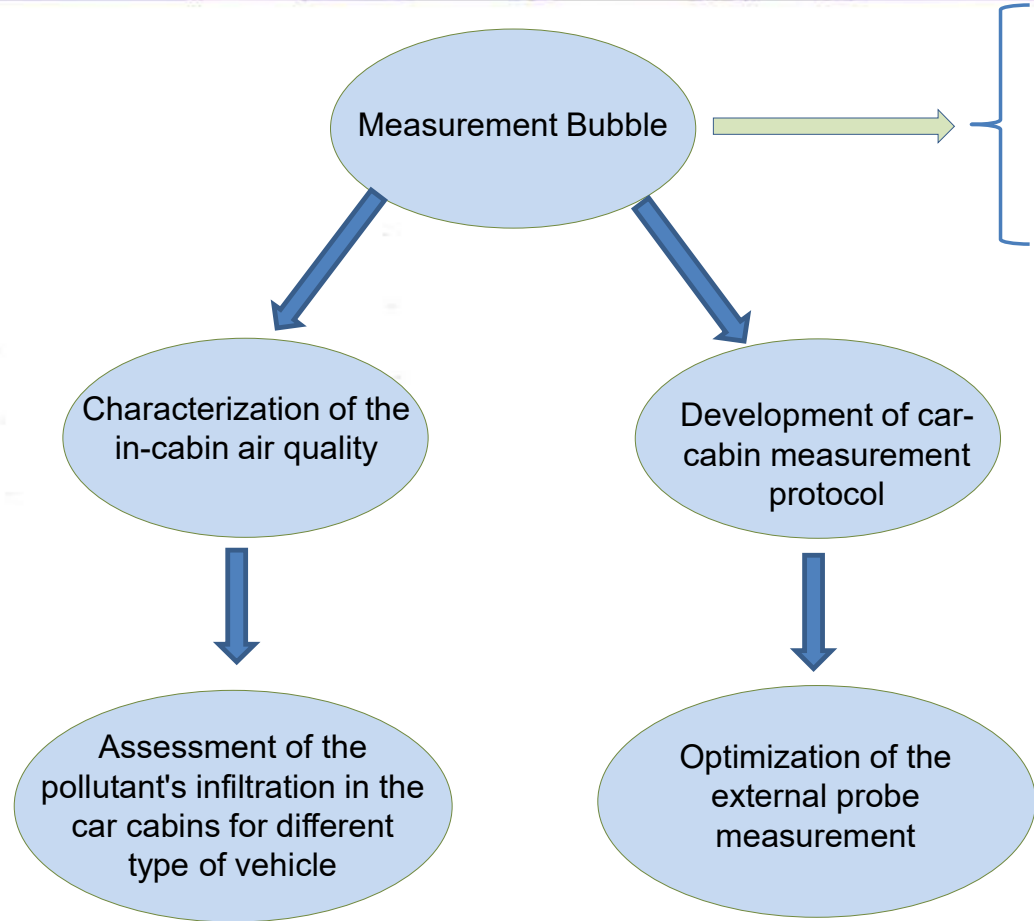
AIRTIGHT CHAMBER FOR VEHICLE CABIN CHARACTERIZATION

- Construction of a closed enclosure (Called the bubble)
- The Dimension (6m long, 3m wide and 2m high).
- Equipped with exhaust gas extraction system
- Air conditioning system to maintain a constant temperature (around 23°C)
- Pollutant injection system.
- Ventilation system to ensure the mixing of pollutants inside the bubble.



Fig 1: Closed chamber (measurement bubble)

AIRTIGHT CHAMBER FOR VEHICLE CABIN CHARACTERIZATION



- Sealing characterization
- Assessment of pollutants concentration homogeneization

AIRTIGHT CHAMBER FOR VEHICLE CABIN CHARACTERIZATION

Particle injection system:

Generation of particles of size between
 $0.01\mu\text{m}$ to $12\mu\text{m}$



Fig 2: AGK 2000
particle generator

Use of compressed nitrogen
as injection gas

Injection rate 4 to
12 l/min

Gas injection:

- CO₂ gas

Measuring instruments:



Fig 3: Grimm Mini Wras

- Particle size measurement in number (Nbr/cm³) and mass ($\mu\text{g}/\text{m}^3$)
- Particle size between 0.01 to $35\mu\text{m}$
- Measurement time (1 measurement / min)



Fig 4: TSI Dust Track

- Measurement in mass concentration (mg/m^3)
- Particle size between 0.1 to $15\mu\text{m}$
- Acquisition time of 1s



Fig 5: TSI 7525 IAQ-Calc

- Measurement of CO₂ gas in ppm
- Range between 0-5000 ppm
- Acquisition time of 1s

AIRTIGHT CHAMBER FOR VEHICLE CABIN CHARACTERIZATION

Bubble tightness:

- Injection of CO₂ (5000 ppm) in the closed bubble.
- Continuous measurement of the concentration evolution of CO₂ inside the bubble (for 15 hours)
- Assessment of CO₂ loss in the bubble in ppm/min.

Results:

- The CO₂ loss is approximately **1 ppm/min (3,5% loss for one measurement campaign)**.

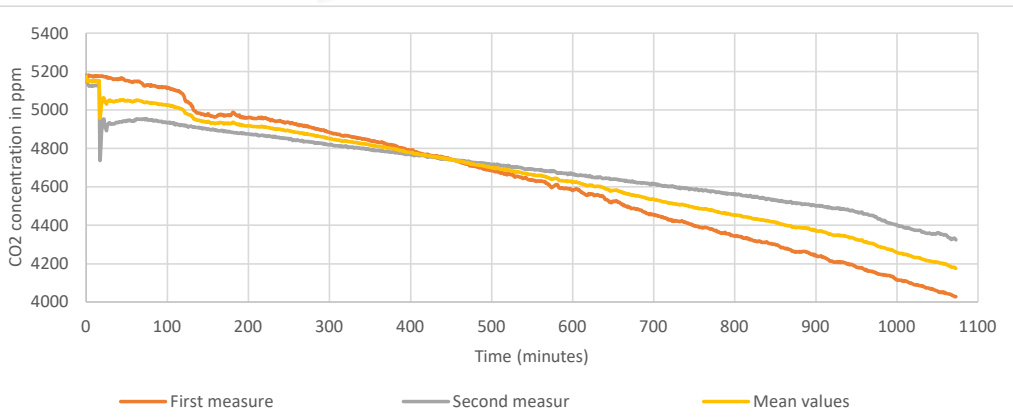
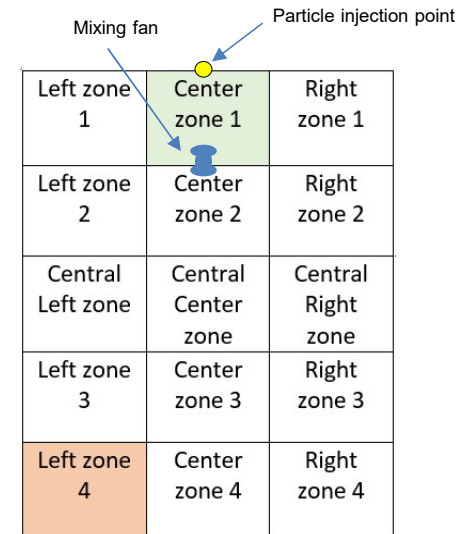


Fig 6 : CO₂ concentration in the bubble

Particle distribution homogeneity

- 15 different Zones in the bubble.
- Injection of fine and ultra-fine particles into the closed bubble (with the activation of mixing fan)
- Measurement of the concentration of particles injected into the bubble in each localized area.
- Quantify the deviations of the concentration in the 15 zones.



Results:

- The maximum deviation is in the zone (center 1) and the zone (left 4) between 124.000 and 115.000 particles/cm³. The difference is around 7%.



EXAMPLE OF CAR CABIN AIR CHARACTERIZATION OF A VEHICLE.

EXAMPLE OF CAR CABIN AIR CHARACTERIZATION OF A VEHICLE

Particle infiltration measurement in the in-cabin of the vehicle:

Objectif:

- Control the concentration of particles (fine and ultra fine) injected into the bubble 120.000 (particles/cm³).
- Maintain the same concentration level (recommended in number and mass) of particles in the bubble (wherever the engine of the vehicle is ON or OFF).
- Measurement of the concentration (in mg/m³) of particles infiltrated into the passenger compartment for the different ventilation speeds and modes.

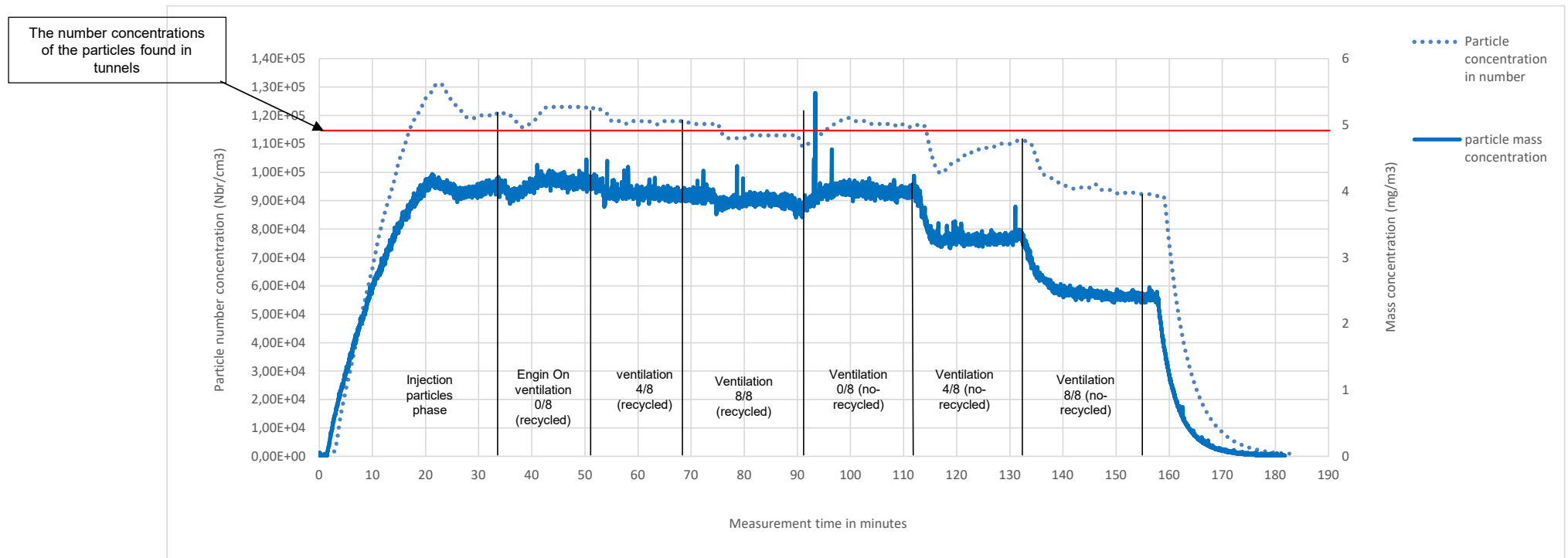


Fig 7: Concentration of particles measured in the measurement bubble

EXAMPLE OF CAR CABIN AIR CHARACTERIZATION OF A VEHICLE

Example of particle infiltration measurement in the passenger compartment of a vehicle :

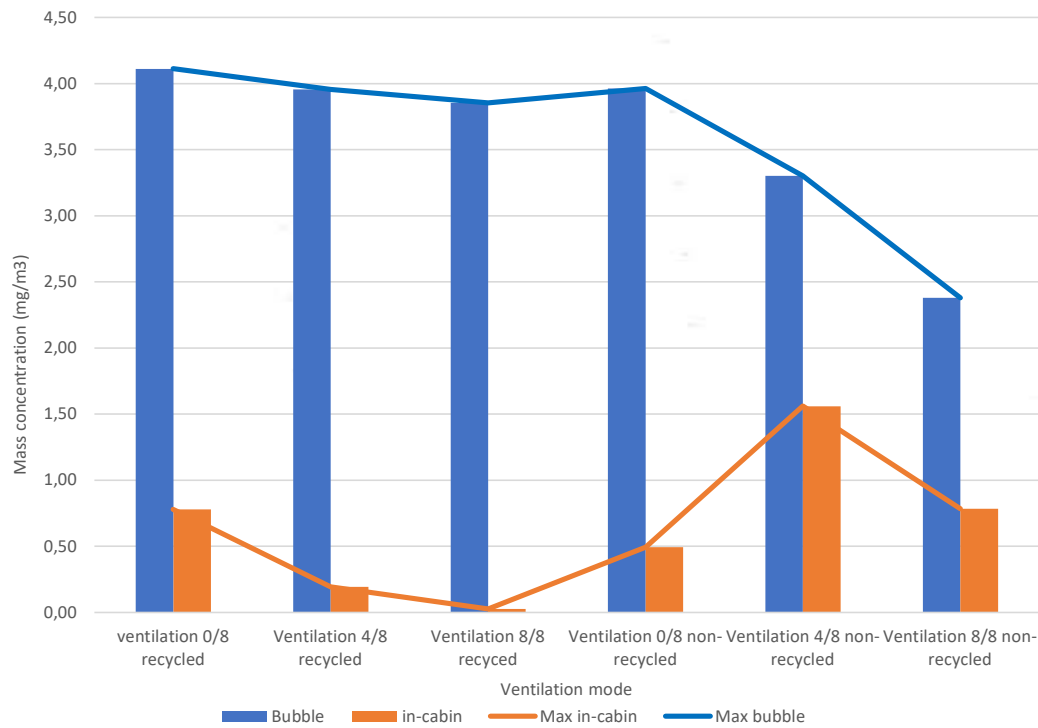


Fig 8: Histogram of particle infiltration in the car cabin(atmosphere with a particle concentration of 120.000 Particles/cm³)

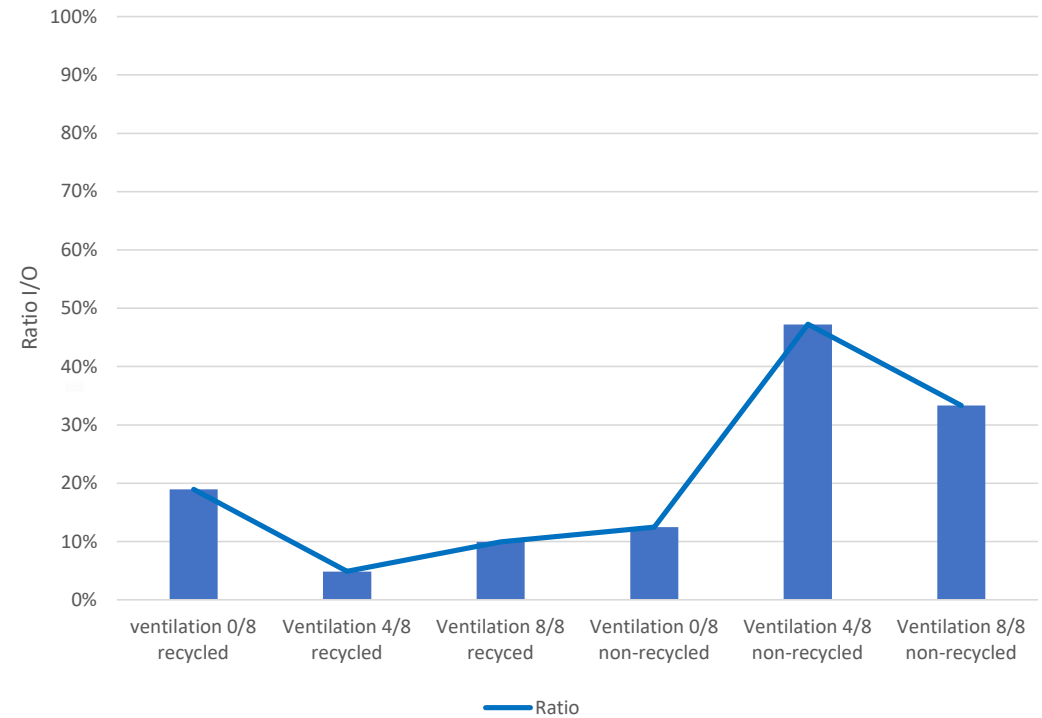


Fig 9: Percentage of particle infiltration in the car cabin depending on the ventilation mode (I/O ratio of mass concentration)



CFD FLOW AROUND THE MEASURING PROBE

CFD FLOW AROUND THE MEASURING PROBE

- The measuring probe is used to measure the concentration of outdoor pollutants
- Numerical simulation helps to understand and predict how the flow behaves around the measurement probe in order to optimize its positioning and inclination.
- The mini-wind tunnel ensures a flow around the probe that reproduces the same flow found when driving

Driving simulation calculation domain:

- The creation of a suitable domain for the achievement of simulations in driving mode.
- The objective is to characterize the structure of the flow around the probe
- Inlet flow velocity: 20 m/s

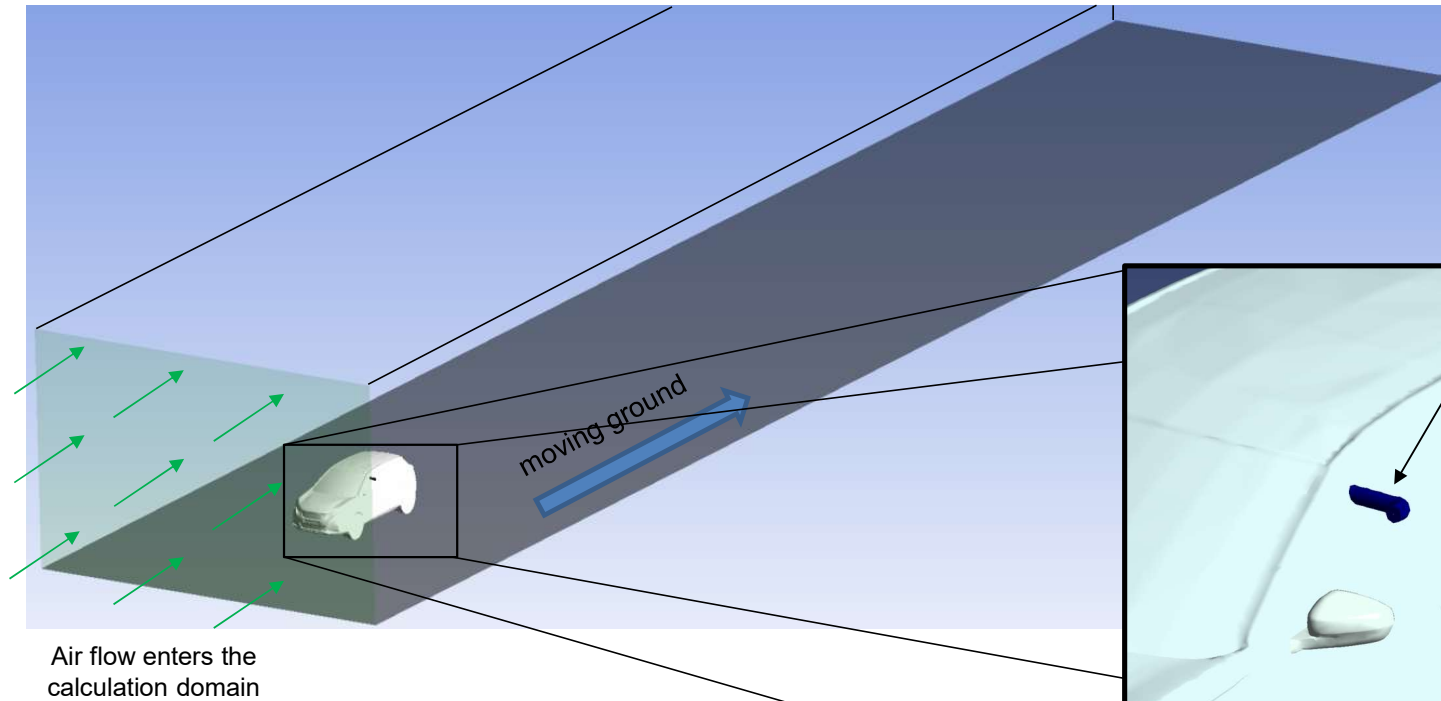


Fig 10: Driving simulation calculation domain

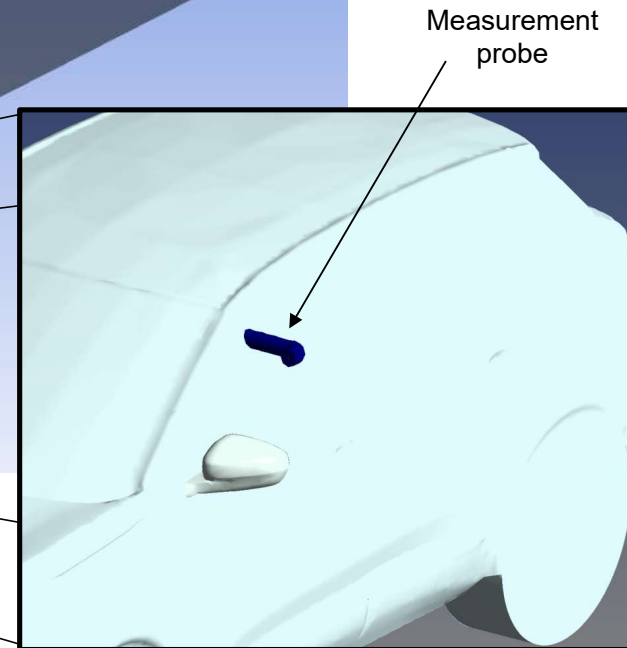
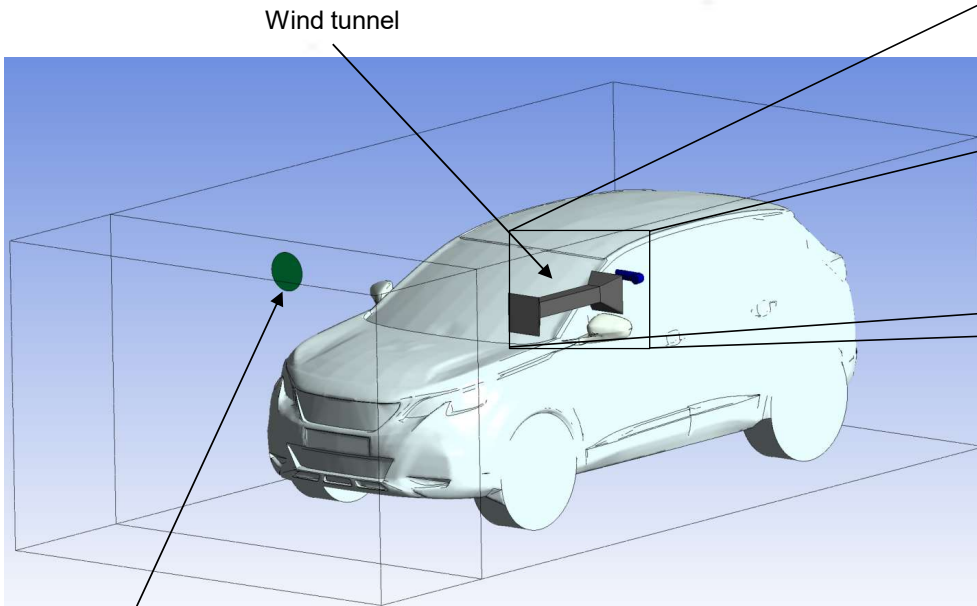


Fig 11: External measurement probe

Mini-wind tunnel simulation calculation domain:

- Design of a system that regenerates the driving flow around the measurement probe in the bubble



Fan

Fig 12: Domain of calculation for simulations with the mini-wind tunnel in the bubble

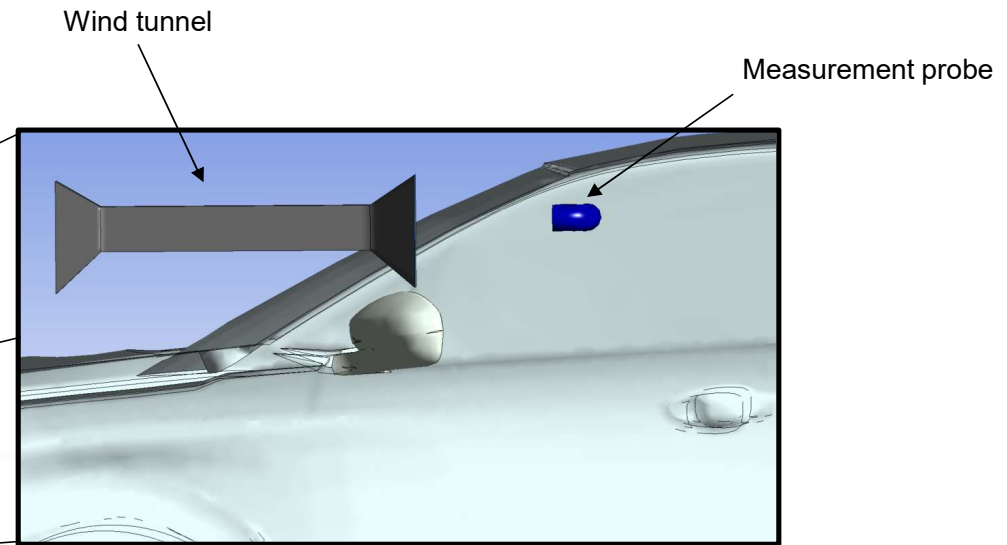


Fig 13: Mini wind tunnel and measuring probe

CFD FLOW AROUND THE MEASURING PROBE

Driving simulation :

- The velocity vector fields represent the structure of the flow around the probe.
- The interaction between the walls and the flow influences the flow turbulent structures and could affect the quality of the concentration measurements.

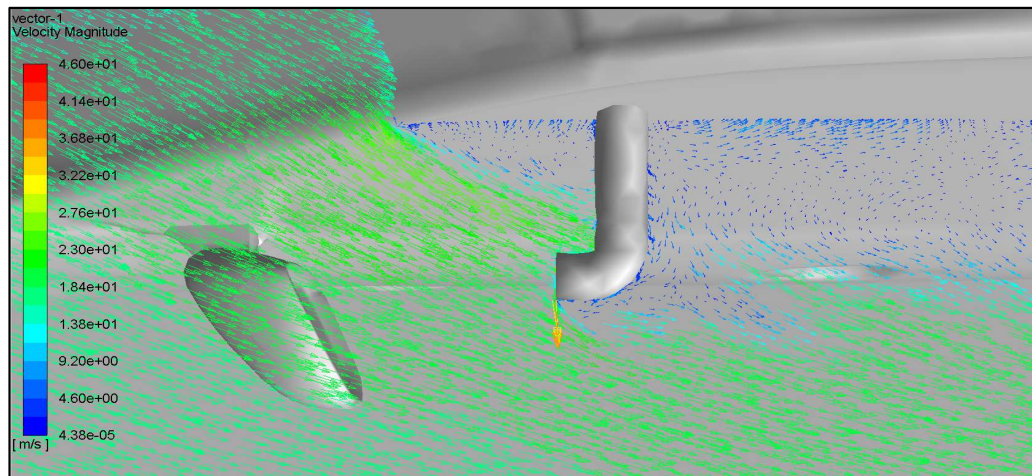


Fig 14: Velocity vector field around the probe in the horizontal plane (driving mode)

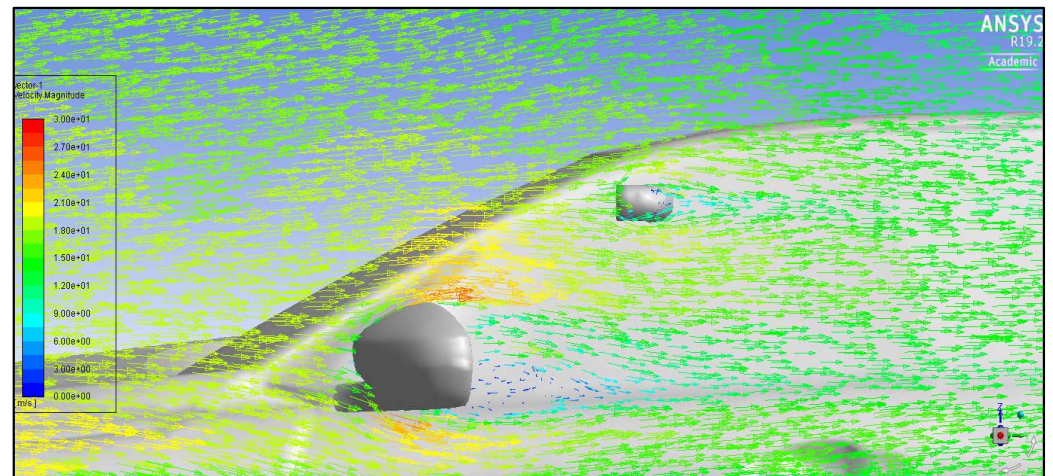


Fig 15: Velocity vector field around the probe in the vertical plane (driving mode)

CFD FLOW AROUND THE MEASURING PROBE

Mini-wind tunnel simulation :

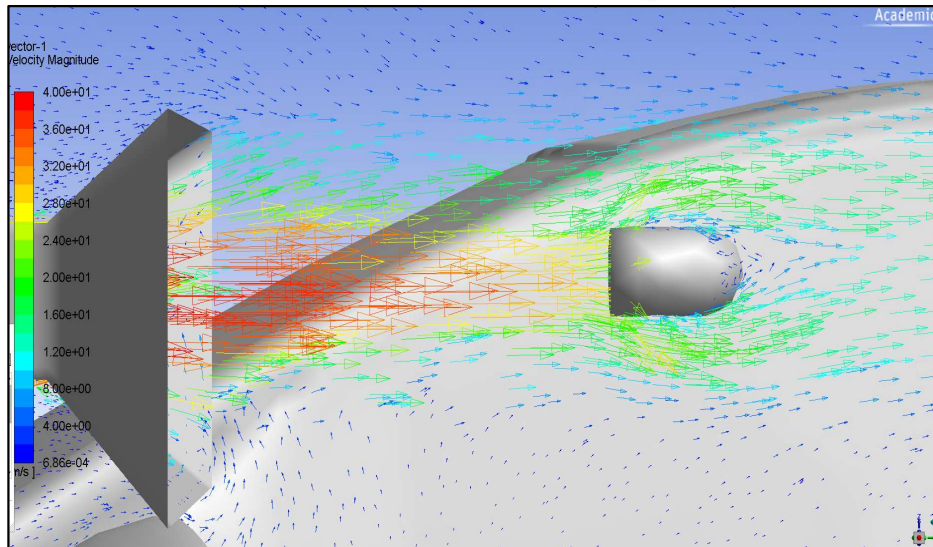


Fig 16: Velocity vector field around the probe in the vertical plane

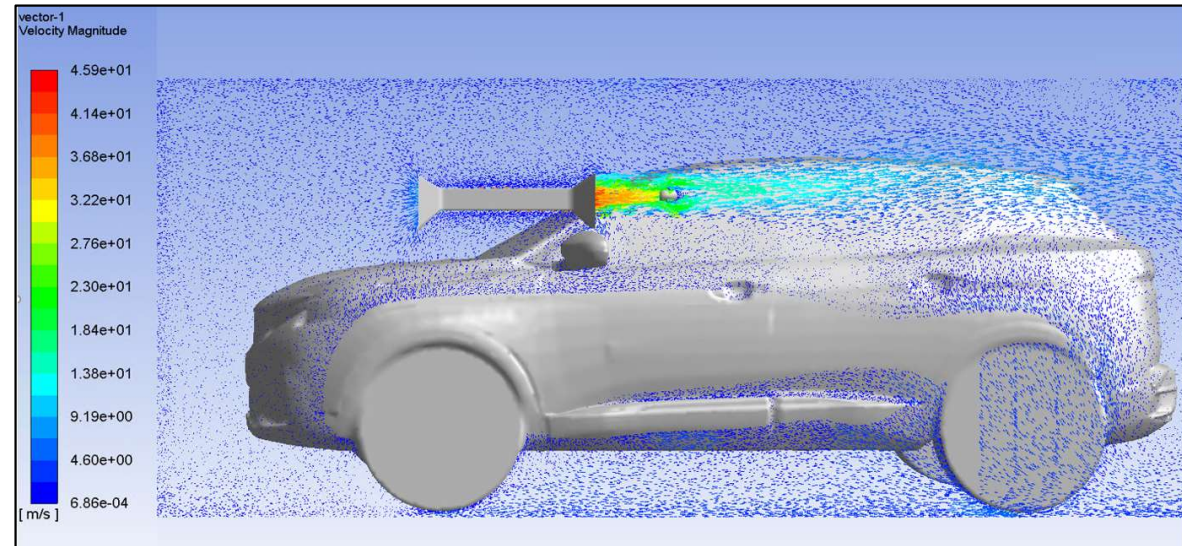


Fig 17 : Velocity vector field in the vertical plane passing through the probe in the bubble

CONCLUSION AND PERSPECTIVES

- Installation a specific bench to characterize the quality of vehicle air cabin.
- The measurement benches can be adapted to any type of motorization as well as to different dimensions of the vehicles
- In addition, this measurement bench will allow the development of a protocol for moving external measurements.



THANK YOU FOR YOUR ATTENTION