Feedback Active Flow Control Investigation on a car model

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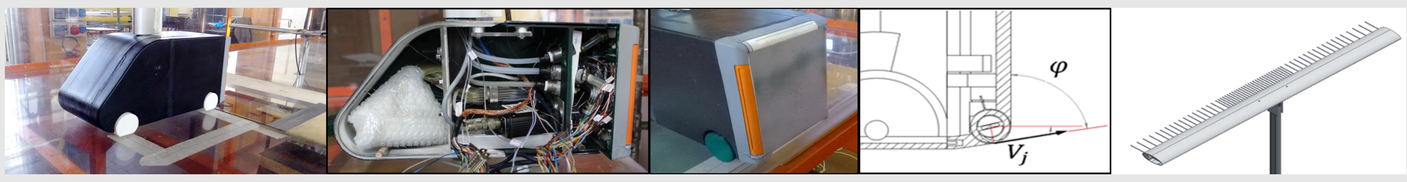
Motivations and objectives

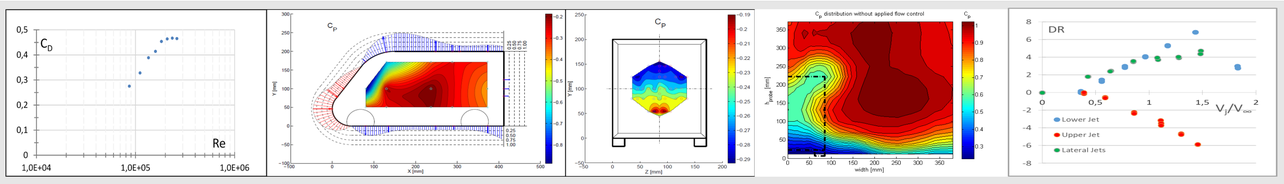
The problem of the emissions of pollutant to the atmosphere, in particular CO2, prompted the governments to take action on this subject: The UE approved a series of norms that **limit the CO2 emissions** on all their forms. This impact directly on the automotive industry, that needs to fit those requirements on their new vehicles. As widely known, the pollutant emissions are consequence of the combustion. So a vehicle that burns less fuel will consequently have less emissions. One way to reduce the fuel consumption (and therefore emissions) is reducing the aerodynamic drag of the vehicle, and the van-like cars are an interesting case to improve due to their bluff body shape. The objective of Our research is to **reduce the aerodynamic drag** of a van-like car model by means of an **Active Flow Control (AFC)** technique based on dynamic jets, with **closed-loop (feedback) control,** using advance data analysis like **Proper Orthogonal decomposition (POD), Cross correlation** and **Wavelet analysis.**

Experiment



A model based on a commercial vehicle scaled 1:10 was tested on an open-circuit subsonic wind tunnel. On the model's surface are 64 pressure taps to obtain the mean pressure distribution, and twelve microphones on the rear base to sense the high-frequency pressure oscillations. The **AFC** is based on four jets are settled on the rear part that can be regulated on angle and intensity. A balance on the top of the test chamber measures the aerodynamic drag on the model, and a "Rake" behind the model measures the total pressure distribution of the model's wake. The methodology for the drag measure was assessed, and the results for the natural and several controlled cases were found.

Previous research activities at PoliTO

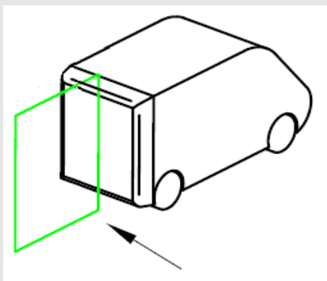


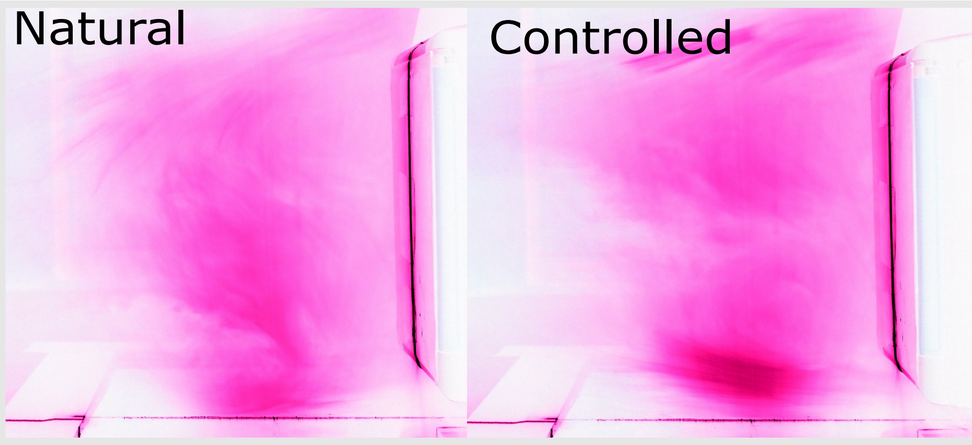
The **AFC** performance was analyzed in terms of **drag reduction (DR)** through several tests, and a particular configuration was found in which the **DR** reaches almost 13%. The **energy budget** analysis between the energy saved by the drag reduction and the energy required by the **AFC**, showed that an overall energy gain can be obtained at a **DR** of about 10%. Finally, the flow structure around and behind the model was determined through the pressure and the wake measurements, showing the flow behaviour for both controlled and natural cases. This research evidenced the control authority of AFC on continuous conditions, but did not describe neither the time-depending AFC capabilities, nor the adaptability of the control systemto different conditions on the flow. These last open questions lead to the new research.

Achievements of the first year

1. Wake visualization (Laser)

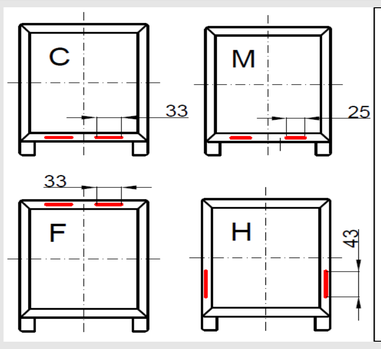
Through a smoke machine and a laser plane settled on different parts of the wake of the model, flow visualizations were obtained. From these, the **topology of the near wake** of the model was identified for the natural and controlled (Max DR) cases. The comparison of these cases (natural and controlled) lead to the identification of a **change in the wake structure**, product of the action of the AFC. This change corresponds with the results shown on a CFD survey performed on a precedent research.

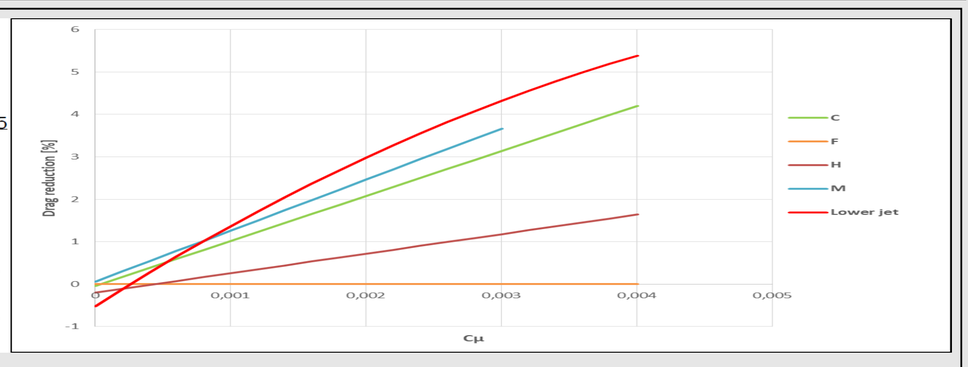




2. Partialized jets test

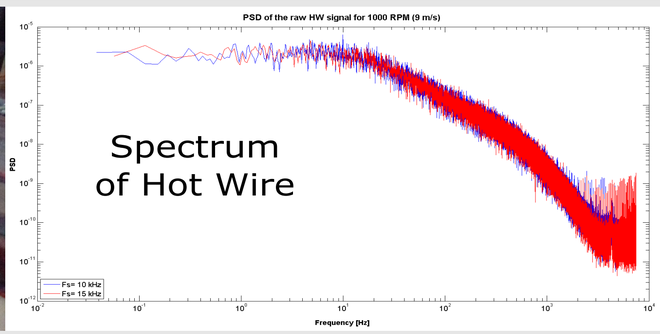
The efficiency of different configuration of jets in terms of **output area and location** was analyzed. For this study, the jets of the AFC were partialized on different configurations and compared with the non-partialized case. This survey showed that the areas **closer to the lower angles** of the rear part are **more suitable in the case of low flow of gases**.





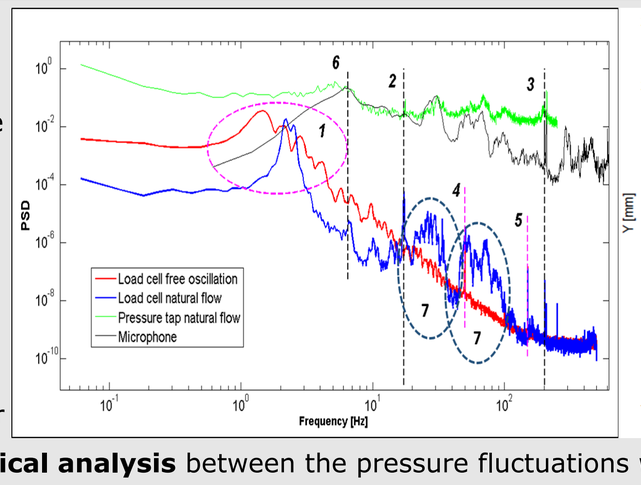
3. Hot Wire measurements

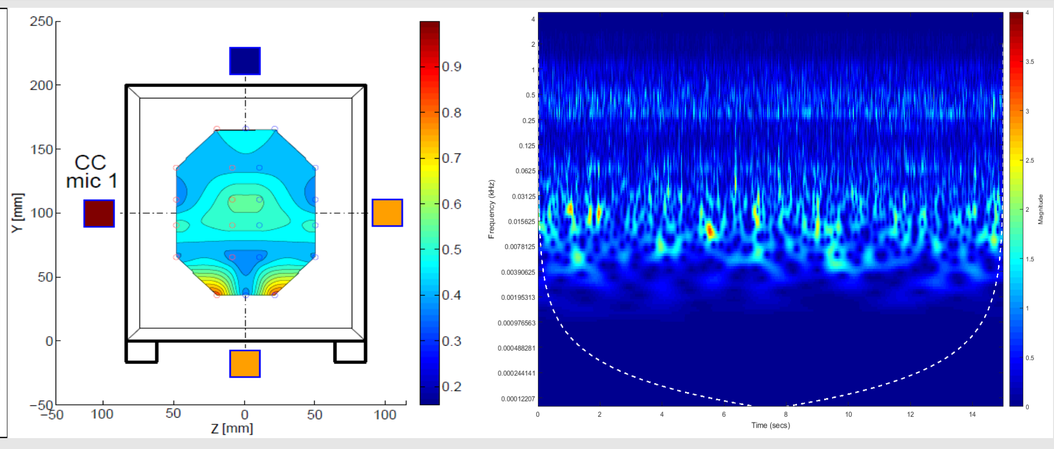
A hot wire measurement technique was included on the new research, in order to obtain **high-resolved time measurements of the velocity**. The first measure performed was the **mean velocity** and **turbulence of the test chamber**: Then, a couple of hot wires were settled on the wake of the model in order to obtain Cross correlations and spectrum from these measurements, to further analyze the wake on natural cases.



4. Advanced data analysis

From the time-dependent pressure fluctuations of the different sensors onboard the model were obtained the **spectra**. From this data we were able to discriminate the spurious effects of the wind tunnel and the test itself, from the data that represents the aerodynamic phenomena around the model. This identified the dominant frequencies characterizing the dynamic behavior of the wake. Later, a **Cross correlation statistical analysis** between the pressure fluctuations was performed, where a high correlation between the lateral and lower parts of the model and the lower-rear base were found. Finally, a preliminary **Wavelet Analysis** was performed. Through this analysis characteristic energetic "zones" were identified, related to the dynamic of the wake.





Second year objectives

- Identification of coherent structures on the wake of the car using advanced data analysis
- Preparation of the experiment focused on feedback control
- Develope a control law for the AFC

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