Summary

In the present thesis a wind tunnel investigation over a 1:10 scaled van model was performed in order to evaluate two different techniques for drag reduction: active flow control (AFC) and platooning of vehicles. The AFC consist in four cylindrical actuators along the trailing edges, with longitudinal slots blowing tangentially to the actuator surface and angled in 65° regarding the model's base. For the platooning evaluation, three replicas of the model were built and then configured in different arrangements to emulate the various positions of a two, three and four vehicle convoy. PIV and Stereo PIV techniques were used to the reconstruct the architecture of the flow field on the model's rear part. The model mounts 64 pressure taps in order to measure the mean pressure in the whole model's surface and 16 microphones on the rear part for pressure fluctuations. Drag measurements were performed through a drag balance mounted on the top of the test chamber and connected to the model by a hollowed beam, that houses the electric lines of the sensors and the tubing for the AFC.

The baseline (non-controlled case, isolated model) presents a drag coefficient of $C_D = 0.45$ at $Re = 2.5x10^5$, typical for this kind of vehicles. The pressure distribution evidence the presence of the A-pillar vortex on the side part and an almost constant pressure distribution on the rear, showing a slight growing tendency towards the bottom. The pressure fluctuations on the rear base were analyzed in the frequency domain highlighting a dominant peak of energy at a Strouhal number of $St = 0.12$, agreeing with the typical vortex shedding frequencies of this kind of vehicles. The mean flow PIV confirm the classic wake structure for squareback bluff bodies, composed by a recirculating flow zone on the near wake and two streamwise counter-rotating vortexes that trail away from the model.

The AFC was first analyzed by using steady blowing. The drag characterization of the individual jets demonstrated that the bottom and lateral jets produce drag reduction, while the top one produces drag increasing. This undesirable effect might be produced by the increased wake asymmetry due to the top blowing. Combined blowing using the lateral and bottom jets further reduces the drag regarding the singe blowing. Varying the blowing speeds of both lateral and bottom jets two main configurations were found: A maximum drag reduction (Max DR) performing $\Delta C_D = -10.6\%$ and a best compromise (BC) given by the maximum values of the ratio between the drag variation and the blowing coefficient $\Delta C_D / C_\mu$, performing a drag variation of $\Delta C_D = -5\%$. A successive energy budget analysis was performed by calculating the efficiency ratio (ξ) given by the power gained by the drag reduction versus the power consumed by the blowing jets, that demonstrates that the BC recovers through the drag reduction five times the power consumed by the jets ($\xi = 5$) while in the Max DR the power spent overcomes the power gain ($\xi = 0.8$). The pressure distributions demonstrate that the AFC only modifies the pressure distribution on the rear part and the drag reduction is a consequence of the increasing base pressure, that grows with the increasing blowing. The PIV and Stereo PIV of the wake for the BC and Max DR cases display a reduction of the recirculation bubble and a reduction of the counter rotating streamwise vortexes. For the Max DR the wake severally changes, further reducing the recirculating bubble and canceling the streamwise vortexes.

The AFC unsteady actuation was analyzed by using a squared waveform and changing

the frequency, duty cycle, minimum and maximum velocities of blowing. In a first stage the pulsed blowing was studied, performing a zero minimum velocity and a maximum equal to the freestream speed. No significant values of drag reduction where found for frequencies ranging between 1 and 50Hz and different duty cycles. Only the bottom jets evidence three drag reduction peaks reaching near the steady blowing values, around the $St = 0.12$ frequency and the two consecutive harmonics for a duty cycle of 30%. This might evidence a response of the wake to the dynamic actuation, but not strong enough to obtain high values of drag reduction. These peaks are not observed when blowing from the lateral or combined jets. Actually, for the lateral jets some peaks of drag increasing were observed. A second study was performed involving the fluctuation of the blowing velocity around the freestream speed, with different ranges of velocities, frequencies and duty cycles. As in the pulsed blowing, the drag results show no improvement regarding the steady blowing.

Lastly, the platooning test were performed using the model replicas. The two-model configuration was extensively analyzed, presenting high values of drag reduction for both vehicles. The increasing of the base pressure of the front vehicle due to the approaching of the following produces a maximum drag reduction of $\Delta C_D = -30\%$ for half model length of distance ($d/L = 0.5$). The rear vehicle sees a drop of the front pressure distribution product of the front vehicle's wake, reaching $\Delta C_D = -42\%$ for the same distance. For convoys of three and four models three characteristic positions were discovered: front, middle and rear models. Independent from the number of components of the platoon, these positions present the same drag variations regarding the distance between models, allowing to extrapolate the platoon to a virtually infinite number of vehicles. The extrapolation shows an asymptotic tendency of the average drag reduction of the platoon for all different d/L distances studied, reaching 90% of this maximum value when the convoy exceeds 18 models.