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## Experimental application of active flow control on a 1:8 scale, simplified truck model

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**Abstract:** The effect of active flow control combining synthetic jets and inclined flaps on the flow behind a 1:8 scale simplified truck model is experimentally studied. Aerodynamic drag and base pressure measurements show that forcing the flow within a given range of actuation frequencies allows reducing the drag. However, results also show that such drag reductions greatly depend on the underside flow velocity.

*Keywords:* heavy vehicles, flow control, drag reduction, experiments.

### 1 Problem statement and experimental set-up

The geometry and the near-wake flow of a truck trailer exhibit two specificities compared to automotive applications:

- the aspect ratio  $H/W$  between height and width of the vehicle is greater than unity;
- the ratio  $U_s/U_\infty$  between the underside and free-stream velocities can reach down to 0.1.

The aim of the present experimental investigation is to study how an active flow control system combining synthetic jets and flaps modifies the drag acting on a 1:8 scale simplified truck model (Fig. 1(a)) showing these two specificities. In such a case, the near-wake flow structure in the trailer vertical symmetry plane consists of a recirculating area dominated by a large vortex structure whose size is close to  $H$ , which recalls backward facing step flows [1] and is a quite different wake flow than the one studied in [2] where a two-dimensional periodic vortex shedding is observed.

The rear part of the model consists of a square-back geometry associated with inclined flaps located on the upper and lateral sides (Fig 1(b)). In the present study, the natural uncontrolled flow over the upper flap is separated. Flow control is generated by synthetic jets driven in open-loop and flowing through four adjacent rectangular slots located downstream the upper edge formed by the model roof and the flap (Fig. 1(c)). The jet is oriented with an angle of  $45^\circ$  with respect to the free-stream flow direction and its time-averaged velocity over the blowing phase is  $8.5 \text{ m}\cdot\text{s}^{-1}$ .

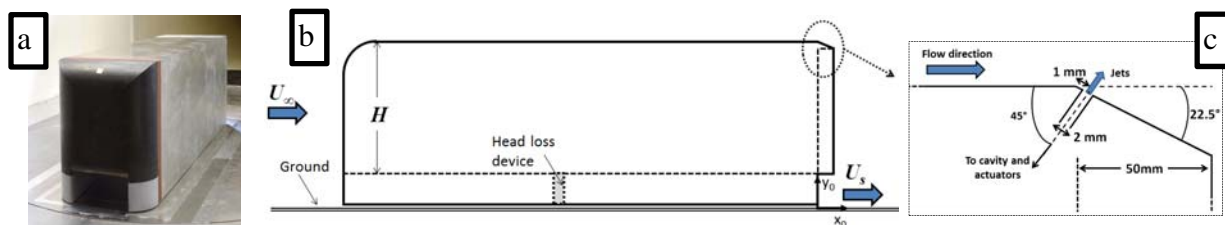


Figure 1: Photo (a) and side view (b) of the model. Focus on the upper flap and the jet slots (c).

The experiments are conducted in a wind tunnel with a free-stream velocity  $U_\infty$  set to  $25 \text{ m}\cdot\text{s}^{-1}$ , resulting in a Reynolds number  $Re_H = U_\infty H/\nu \approx 7.10^5$ . The model lies on two lateral skirts, guiding the underside flow up to the model rear end. A specific head loss device is positioned between these two skirts, thus reducing the mean underside velocity  $U_s$ . In this study, two cases with  $U_s/U_\infty = 0.1$

and 1 are investigated. Among the different measurements performed, aerodynamic drag, provided by a 1-component balance, and static pressure at the model base will be considered.

## 2 Results and discussion

The evolution of the drag gain with the actuation frequency  $f_{ac}$  is given in Fig. 2(a) for the two underside configurations. The tests in the configuration  $U_s/U_\infty = 1$  revealed a drag penalty over the tested range of  $f_{ac}$ . In the configuration  $U_s/U_\infty = 0.1$ , representative of heavy vehicles, actuating the synthetic jets at low frequency (around 30 Hz) results in a significant drag increase, whereas a drag reduction up to about 4% is obtained for the highest value of  $f_{ac}$ . The difference at high actuation frequency emphasizes the crucial of the underside flow velocity on the flow control efficiency.

The static pressure coefficient  $C_p$  distribution on the model rear base is given in Fig. 2(b) for  $U_s/U_\infty = 0.1$ . Two cases are plotted: the reference case without control and a controlled case ( $f_{ac} = 200$  Hz) for which a drag reduction is obtained in the explored frequency range. These maps show that control, although applied at the upper edge only, increases the rear base wall pressures of nearly 18% compared to the reference case. However, the generation of the aerodynamic perturbation and the curvature of the streamlines around the edge also induce an important decrease of the mean static pressure on the upper flap surface. Therefore, the overall drag reduction appears to be mainly the result of a balance between upper flap and rear base wall pressure modifications: the evolution with  $f_{ac}$  of the overall contribution of wall pressure maps including rear base and flap weighted by geometric parameters shows a very good agreement with the drag measured with the balance (Fig. 3) in the explored frequency range.

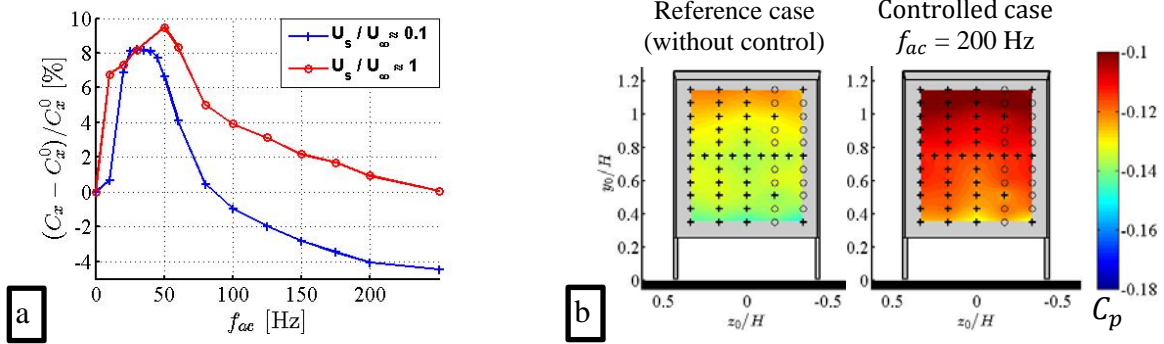


Figure 2: (a) Drag evolution with  $f_{ac}$  for the two tested underside flow configurations.  $C_x$  is the drag coefficient obtained by balance measurements ;  $C_x^0$  is the reference value with control off. (b) Base static pressure coefficient distribution for the configuration  $U_s/U_\infty = 0.1$ .

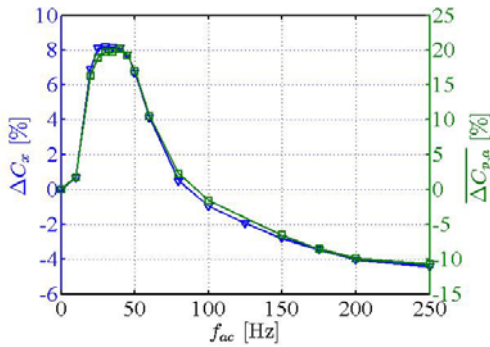


Figure 3: Evolution of the drag gain (blue line) and spatial averaging of flap and rear base wall pressure (green line) with  $f_{ac}$ .

## References

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