ACTIVE FLOW CONTROL AROUND SIMPLIFIED GROUND VEHICLES

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INTRODUCTION

With the evolution of human being activities, the saving of energy becomes the main challenge of the next decades. Due to the huge increase of the number of cars and trucks in some countries, the consumption of oil by ground vehicles becomes disturbing and there is a real need to decrease it. When three-dimensional bluff bodies are moving in the vicinity of the ground, they generate a turbulent flow as several separations occur along the body from the front to the back and in the wake. The resulting recirculation zones contribute to a significant part of the drag coefficient, in particular at the back \cite{3}. A way to reduce the drag coefficient of such vehicles is to control the flow around them. Here, actuator jets are localized on the appropriate places of a three-dimensional Ahmed body with a rear window (a simplified car benchmark) on top of a road in order to change the vortex dynamics and to get a drag reduction. Here, the Ahmed body is considered with a twenty-five degrees rear window.

OUTLINE OF THE METHOD

A global simulation is proposed using the penalization method \cite{1} which consists in adding a term \( U/K \) in the momentum equation of Navier-Stokes system on the velocity \( U \) with \( K \) a non dimensional permeability coefficient. Then it is possible to represent the flow around an obstacle by changing the value of \( K \). Let \( L, W \) and \( H \) be the length, the width and the height of the Ahmed body, \( \Omega = (0, 12H) \times (0, 6H) \times (0, 4H) \) the computational domain, \( \partial \Omega = \Gamma_D \ast \Gamma_0 \ast \Gamma_N \) where \( \Gamma_D \) is the entrance section, \( \Gamma_0 \) is the road and \( \Gamma_N \) corresponds to the artificial frontiers, the computational domain is shown in Fig. 1.

Here, the solid body is considered as a porous medium of zero permeability while the fluid is considered as a porous medium of infinite permeability. Numerically, the values are respectively \( K = 10^{-8} \) and \( K = 10^{16} \). The computational technique is a DNS approach based on high order finite differences. The discretization is achieved by a second order Gear scheme in time with explicit treatment of the convection term. All the other terms are considered implicitly \cite{2}. To get a high performance, a multigrid method with a sequence of grids from a coarse 12x6x4 cells grid to a fine 768x384x256 cells grid, is introduced. The whole method is efficient, accurate and stable enough to make 3D direct numerical simulations of complex flows. As the flow is computed inside the solid body, we can compute the drag and lift forces by integrating the penalization term on the volume of the body neglecting the time term and the convection term, for instance \( F_d = -\int_{body} \text{div}(U,p)d\Omega \approx \int_{body} U/Kd\Omega \). Then the drag coefficient \( C_d \) is given by \( C_d = 2F_d/WH \).
CONTROL OF THE 25 DEGREES REAR WINDOW AHMED BODY FLOW

This flow is a genuine three-dimensional flow with longitudinal vortices on both sides of the rear window (figure 2). Consequently, the results presented are performed in three dimensions.

It is not possible in a real car configuration to put control devices on the rear window except on its boundary. Here we propose to add blowing or sucking jets to control the flow. One of the control attempts is to reduce the intensity of the longitudinal vortices adding a longitudinal jet line (the thickness is \( h_j = 0.024H \) on 90% of the length) on both sides of the rear window (figure 3).

The effect of the control is close to our attempts as there is a strong decrease of the drag coefficient on the rear window and even in front of the body. The size of the longitudinal vortices is increased by the blowing but their strength and their effect on the body are decreased significantly (figure 4). The effect is very clear on the \( C_p \) profiles presented in figure 5, the \( C_p \) values are much higher on the top of the rear window (0 corresponds to the bottom and 1 to the top). Indeed, the mean value in the upper half on the edge goes from -0.55 to -0.34. Consequently, the drag coefficient reduction reaches 11%, from 0.371 to 0.332.

CONCLUSIONS

Active control processes are proposed to reduce the drag coefficient of the 25 degrees rear window Ahmed body. A very good reduction of the drag forces is achieved on the rear window with active control using blowing or sucking jet lines.

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REFERENCES


Figure 2: The mean CPi isosurface colored by CP values, without control.

Figure 3: Longitudinal control jet lines.

Figure 4: The mean \( C_{Pi} = 0.8 \) isosurface colored by \( C_P \) values for the longitudinal active control.

Figure 5: Mean \( C_P \) profile on the edge of the rear window for the uncontrolled and the longitudinal active controlled cases (\( D/d \) is the relative position on the rear window.)