Imperial College London

An investigation on the effect of rear underbody diffusers over the flow around automotive bluff bodies

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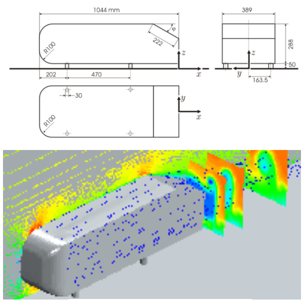
ABSTRACT

This is a research project in the field of fluid dynamics for a double PhD program between the University of Sao Paulo and Imperial College. The main objective concerns the investigation of mechanisms for drag reduction and lift increment of automotive bodies by interfering with the flow at the rear underbody portion equipped with a diffuser. The automotive bluff body studied is an Ahmed Body with 25º slant angle in order to generate a 3D flow.

This work is mainly conducted by using Nektar++ for the validation of physical measurements and for the flow characterization in the Ahmed Body as a function of the of the underbody diffuser angle, length and ground height.

FIGURE 1



NEKTAR++
SPECTRAL/HP ELEMENT FRAMEWORK

The Ahmed body represents a simplified, ground vehicle geometry. Its shape is simple enough to allow for accurate flow simulation but retains some important practical features relevant to automobile bodies.

The slant angle of 25 degrees was chosen due to the fact that it was characterized as a high 3D flow, by generating 2 vortexes on the slant.

The study aims to understand the phenomena between a 3D flow and the effect and efficiency of the underbody diffusers.

Nektar++ is employed as the main tool to characterize the flow interactions and quantify both lift and drag coefficient.

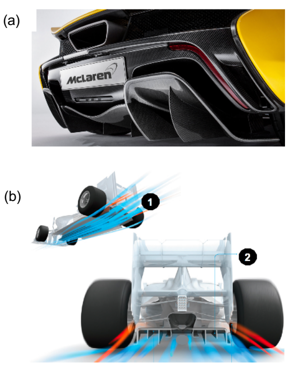
UNDERBODY DIFFUSERS

Diffusers can be defined as aerodynamic devices, which are usually assembled on the rear portion of the underbody in ground vehicles, and its main purpose is to increase the downforce and provide a smooth transition from underbody flow back to free stream.

The downforce on the underbody is generated mainly due to the Venturi's effect and the diffuser intensifies this effect because its geometry curves the streamlines, which increase flow speed and reduce pressure.

The diffuser also acts as an expansion chamber to slowly re-integrate the air as it exits from underneath the car to the free stream. Smoothing the transition, turbulence and drag in the car's wake are improved.

FIGURE 2



(a) Image the rear underbody diffuser of a McLaren P1. Diffuser efficiency increases for sport and race cars due to the need for downforce without compromising the drag.

(b) Schematic view of the underbody and the diffuser on a race car.

1- Pathlines on the underbody and the exit of the diffuser. Race cars have an inclined underbody, in order to increase downforce;

2- Diffuser from a rear view where the flow from the underbody is seen in blue colour and the wheel and outside flow is coloured in red.

ACKNOWLEDGEMENTS

Department of Aeronautics – Imperial College London

NDF – Núcleo de Dinâmica e Fluidos

Escola Politécnica da Universidade de São Paulo

CNPq

OBJECTIVES

The PhD work is divided into two main portions:

First portion consider a backward-forward step to be both tested in the water channel and simulated on Nektar++, in order to determine a correlation between the cases, ensuring the reliability of Nektar++ and methodology applied in this work.

The second portion will consider only CFD simulations in order to understand the effect of the rear underbody diffuser on the lower rear portion of the Ahmed Body and a combination of proposed underbody diffuser angles, lengths and ground height, in order to understand its behaviour on drag, lift and also identify the wake profile.

METHODOLOGY

A backward-forward step is assembled on NDF's water channel in order to verify the velocity fields by PIV measurements. Results obtained on the physical test are compared with the same case tested using Nektar++ for validations purposes. The parameters used for both cases are:

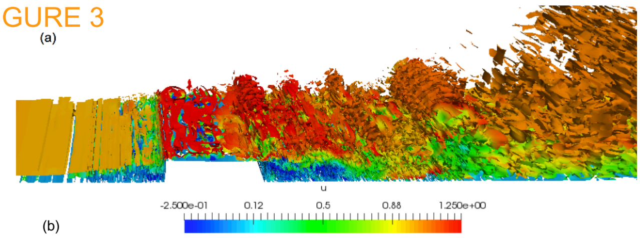
- Re=100,000, based on the step height;
- Boundary layer height of 20mm on the ground;
- Inflow velocity profile for the simulation: $1-\exp(-6000*y^2)$;
- 2D mesh ~4,000 elements (Tria/Quad) 4^{th} order;

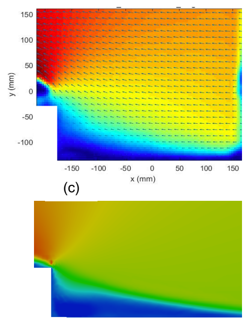
RESULTS

Results were obtained based on a 2.5D simulation: 2D based mesh considering 16 Fourier planes for the span wise direction. Parallel run considering 16 CPUs was used for this 4th order polynomial mesh case.

Validation results comparing velocity fields obtained in both PIV measurements and on Nektar++ indicate the similar velocity trend for the backward-forward step.

FIGURE 3





(a) Q-Criterion contour on the Backward-Forward step 2.5D simulation coloured by u velocity.

Comparison between the average velocity fields measured on the water channel test of the backward-forward step and same case reproduced on Nektar++. Measurements were taken on the middle plane for both cases.

(b) Middle plane velocity field, obtained by PIV on water channel test.

(c) Middle plane velocity field from Nektar++ 2.5D simulation (a).

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