CFD ANALYSIS ON AERODYNAMIC EFFECTS ON A PASSENGER CAR

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Abstract - Performance, Handling, Safety, and Comfort of a passenger car aresignificantly affected by its aerodynamic properties. Getting high power under the normal conditions is not enough to judge the performance of the car. Aerodynamic properties must be considered for the purpose of studying the drag and stability performance of a car. In order to improve car aerodynamic drag and its stability, an aerodynamic device is needed such as Spoiler. Spoiler is an aerodynamic device that functions to slow down and collect air, causing it to stagnate. This device creates an area of high pressure to replace the usual low pressure over the trunk resulting increasing stability.

The objective of this study is to investigate the effects of aftermarket spoiler to car aerodynamics drag and stability. Several spoilers design is attached at rear and roof parts of base line model. Both Base line model, rear and roof spoiler models are built in CAD software. The CAD mode then, either with or without rear and roof spoiler are analyzed in CFD software to estimate the drag and lift force which is acting on the car.

Taking CFD software as the platform and the car as the research object, the air's resistance coefficients and speed are solved by using k-ε equations and dynamic mesh method and taking boundary conditions such as 100 kmph. The finite volume method is used to discrete the governing equations, Then CAD data , either with or without rear and roof spoiler are analyze in CFD software to estimate the drag and lift force which is acting on the car. Force, drag and lift coefficient values will be determined in order to study their effect to drag and stability. Some limitations occurred due to the complexity of the design. From the result, compared to with or without rear and roof spoiler roof is best in increasing stability of car at high speed.

Keywords: Aerodynamic Drag, Coefficient of Drag, Coefficient of Lift, Tail Plate, Wind tunnel simulation, PTC Creo, ANSYS FLUENT, Generic passenger car, CFD.

1. INTRODUCTION

The regulation of greenhouse gases to control global warming and rapidly increasing fuel prices have given tremendous pressure on the design engineers to enhance the current designs of the automobile using minimal changes in the shapes. To fulfill the above requirements, design engineers have been using the concepts of aerodynamics to enhance the efficiency of automobiles. Although aerodynamics depends on so many factors, this thesis concentrates on external devices, which affect the flow around the automobile body to reduce the resistance of the vehicle in normal working conditions.

2. PRINCIPLES OF SPOILER SYSTEM

Spoilers are added to cars and other vehicles to make them more aerodynamic. Most spoilers are attached to the rear of a car, but they can also be found on the front. Various types and the positioning of the spoilers can do different things to improve a car's performance. However, the main reason people install spoilers is to allow for better airflow over and around the car, which in turn creates better grip or traction on the road. Cars that run at high speeds often encounter control problems. That's because at high speeds, the increased air flow creates too much lift, which can be especially dangerous when the car makes a turn, as this can make it fly off the road and lose control.

2.1 Spoiler Types

I. Front spoiler
ii. Lighted Spoiler
iii. Pedestal Spoiler
iv. Roof Spoiler
v. Lip Spoiler
vi. Truck spoiler

I. Front spoiler
This accessory is usually made of lightweight metal or plastic placed beneath the front bumper of a vehicle and intended to increase aerodynamics by blocking the flow of turbulent air under the chassis.

ii. Lighted Spoiler
Lighted spoiler provided with the lights you spoiler will not only ensure optimal brightness and visibility from behind, but also add a stylish accent to the rear of the vehicle, which is noticeable both in the daytime and in the nighttime.

iii. Pedestal Spoiler
The post spoiler is a popular aerodynamic addition, which is positioned on the top of the vehicle's trunk. This automotive accessory can improve stability of the car at a high speed for a performance benefit on the street.A well-designed spoiler can both modify the look of the car and improve its performance.

iv. Roof Spoiler

Roof spoiler is an aerodynamic device that is usually attached to the rear of car's roof. It is custom designed to fit the upper window section and installs directly above the glass.

v. Lip Spoiler

Lip spoiler is a best choice for the driver who prefers a more subtle and at the same time appealing upgrade. Installed on the lip of the trunk, this styling accessory delivers a sporty image that is easy to be recognized. The lip spoiler can peer off the rear of the automobile without being too tall or wide. It also underlines a sleek lines of the car.

vi. Truck spoiler

When attached to any truck's rear, these accessories make it appear aggressive like a roadster. Different types of truck spoilers are suitable for different types of truck brands and their models.

3. LITERATURE SURVEY

Mustafa Cakir [1] , in this paper,"CFD Study on Aerodynamic Effects of a Rear wing/spoiler on a passenger vehicle", The aerodynamic lift, drag and flow characteristics of a high-speed (~65 mph) generic sedan passenger vehicle with a spoiler and without a spoiler situations were numerically investigated. The numerical analyze of high-speed passenger car with first rear spoiler design (case #2, which was a wing style spoiler) has showed that the aerodynamic drag is reduced from 0.232 to 0.192, which is 17% drag reduction, and it also increases negative lift by reducing the lift coefficient from -0.222 to -0.239, which is 7% lift reduction. McKay, Noah J[7], Aerodynamics plays a very important role in motorsports. Car manufacturers around the world have been fascinated and influenced by the various aerodynamic improvements that are used in racing. There has been a constant effort on their side to incorporate these changes to road vehicles not just as an aesthetic design feature but also since they believe that these features can contribute to improving fuel economy and vehicle handling. One of the main areas of concern in racing is to balance aerodynamic forces and to streamline the air flow across the body towards improving stability and handling characteristics, especially, while cornering. At present, formula racing cars are regulated by stringent FIA norms, there is a constraint for the dimensions of the vehicle used, engine capacity, power output and emission. It is difficult to obtain the optimum aerodynamic performance with the existing racing car. There is a need for improvement in the aerodynamic performance of these race cars by using add-on devices locally with different configurations to streamline and channelize the airflow besides reducing aerodynamic forces and providing stability that improves cornering and handling characteristics.

Aniruddha Patiletal[9] The development of low form factor flight controls is driven by the benefits of reducing the installed volume of the control device and/or minimizing the change in external geometry, with particular application to flight control of low observable aircraft. For this work, the term „low form factor" does not refer to the aspect ratio of the control device rather the overall installed volume. This thesis compares the use of low form factor geometric and fluid devices on a NACA 0015 aerofoil section through two-dimensional numerical analysis and low speed wind tunnel experiments. The geometric spoiler is implemented as a small (boundary layer scale) variable height tab oriented normal to the local surface, referred to as a Micro Geometric Spoiler (MiGS). The fluidic spoiler is implemented as an air jet tangential to the local surface acting in the forward direction, referred to as a Counter-Flow Fluidic Spoiler (CFFS). Two chord wise spoiler locations were considered: 0.35c and 0.65c. Numerical analysis was undertaken using a commercial CFD code using an unsteady solver and k-omega shear-stress-transport turbulence model. Experimental forces and moments were measured via an overhead force balance, integrated surface pressures and pressure wake survey. Device performance is assessed against the magnitude of control achievable compared to macro scale spoilers and trailing edge controls (effectiveness), the ratio of aerodynamic output to control input (efficiency or gain), the shape of control response curve (linearity), and the degree of control cross coupling.

4. MODELLING

4.1 PTC Creo Parametric

The flagship application in the PTC Creo Suite, PTC Creo Parametric is the only software you need for 3D CAD. With PTC Creo Parametric, you can seamlessly combine parametric and direct modeling; open non-native CAD data and collaborate with almost anyone thanks to Unite technology; and relax knowing all downstream deliverables will update automatically. Combine this range of capabilities with ease-of use, and you have a product design accelerator.

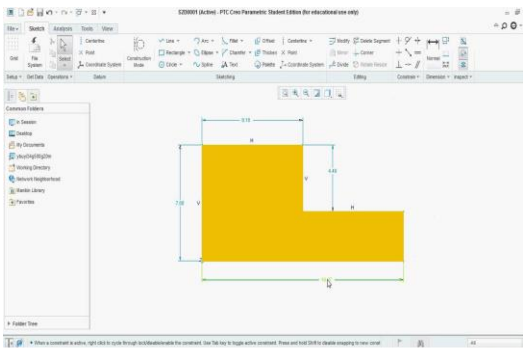

Figure 1: 3D elements/ Direct Modeling

4.2 COMPUTATIONAL FLUID DYNAMICS

"CFD (Computational fluid dynamics) is a set of numerical methods applied to obtain approximate solution of problems of fluid dynamics and heat transfer."According to this definition, CFD is not a science by itself but a way to apply methods of one discipline (numerical analysis) to another(heat and mass transfer).The physical characteristics of the fluid motion can usually be described through fundamental mathematical equations, usually in partial differential form, which govern a process of interest and are often called governing equations in CFD. Jiyuan Tu, Guan Heng Yeoh and Chaoqun Liu has discussed how to solve mathematical equations with using CFD.

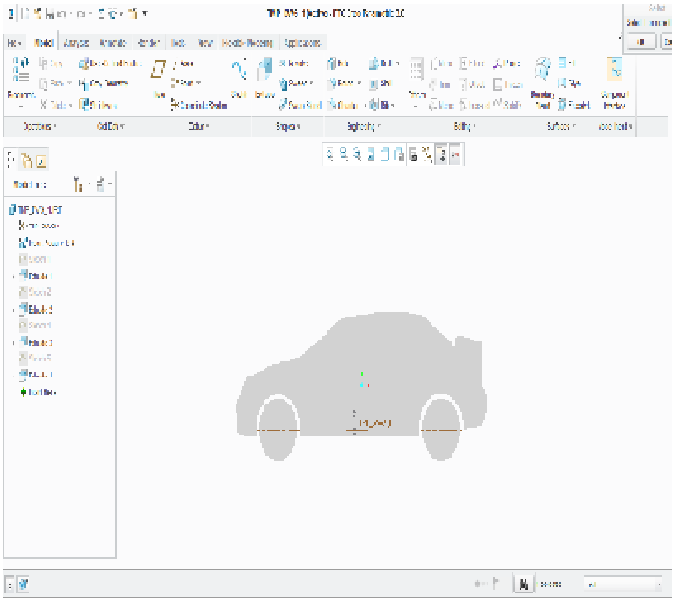

Figure 2: Dimensions of the generic vehicle model

5. RESULTS & DISCUSSIONS

Results:

- Total pressure contour
- Velocity contour

Conditions:

- ❖ Representation on a 3D model
- ❖ Representation on a axial plane

- ➢ Without spoiler
- ➢ With rear spoiler
- ➢ With roof spoiler

5.1. Representation of Contours using 3D Model

5.1.1 Total Pressure Contours

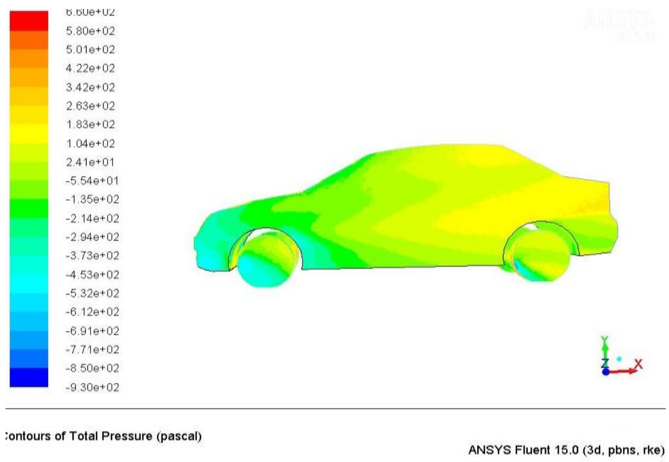

Figure 3: Total Pressure Contour without Spoiler Using 3D Model

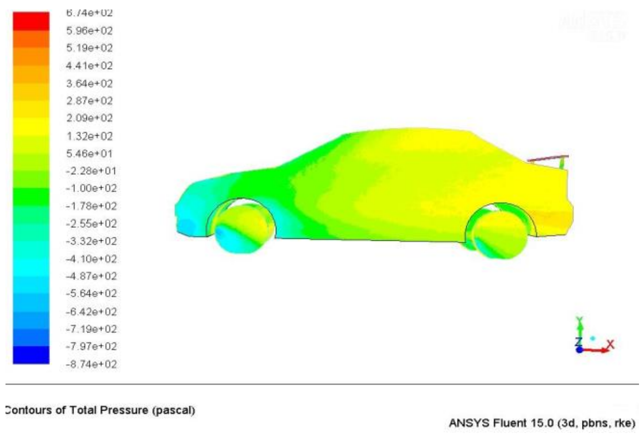

Figure 4: Total Pressure Contour With Rear Spoiler Using 3D Model

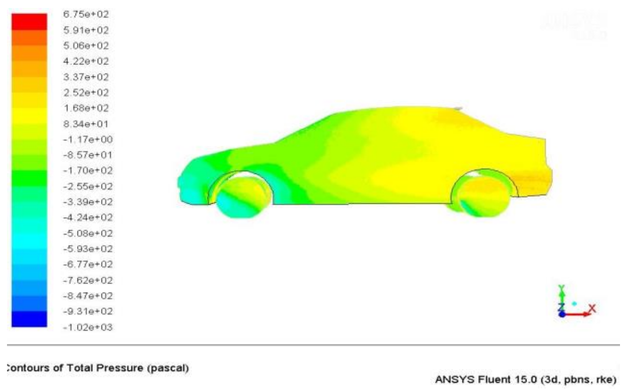

Figure 5: Total Pressure Contour With Top Spoiler Using 3D Model

5.1.2. Velocity Contours

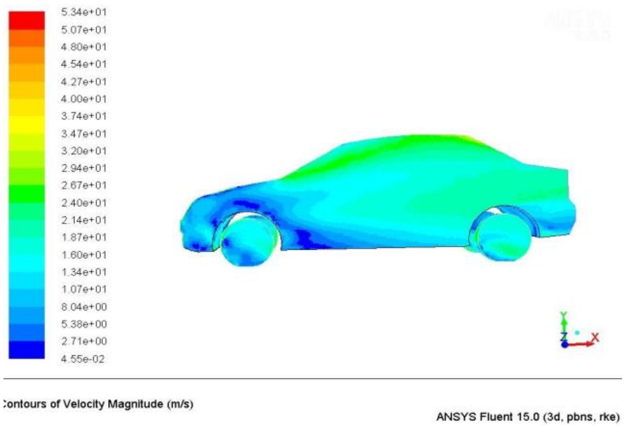

Figure 6: Total Velocity Contour Without Spoiler Using 3D Model

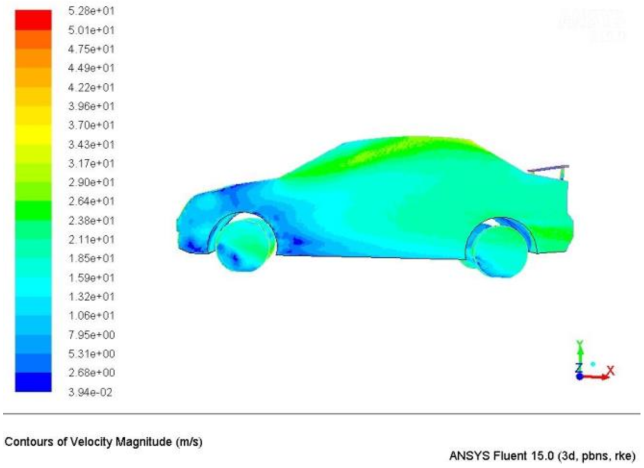

Figure 7: Total Velocity Contour With Rear Spoiler Using 3D Model

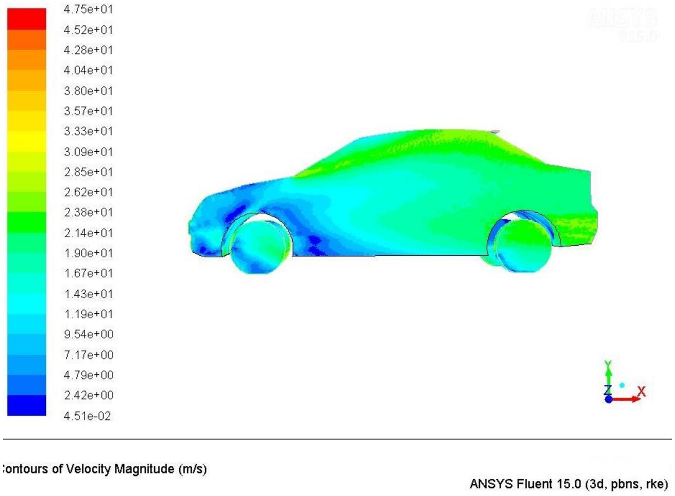

Figure 8: Total Velocity Contour With Top Spoiler Using 3D Model

5.2 Representation of Contours Using Axial Plane

5.2.1 Total Pressure Contours

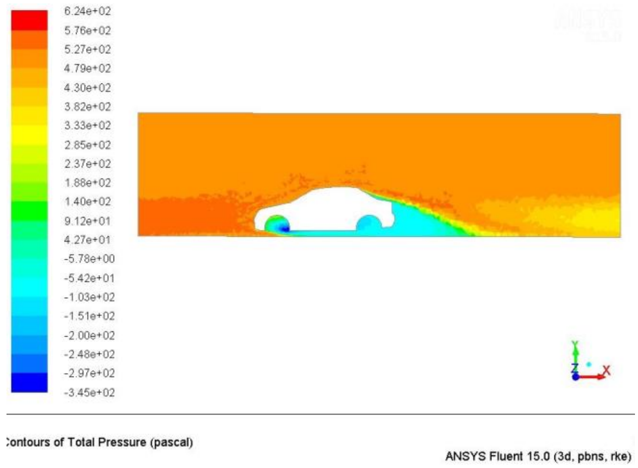

Figure 9: Total Pressure Contours without Spoiler Using Axial Plane

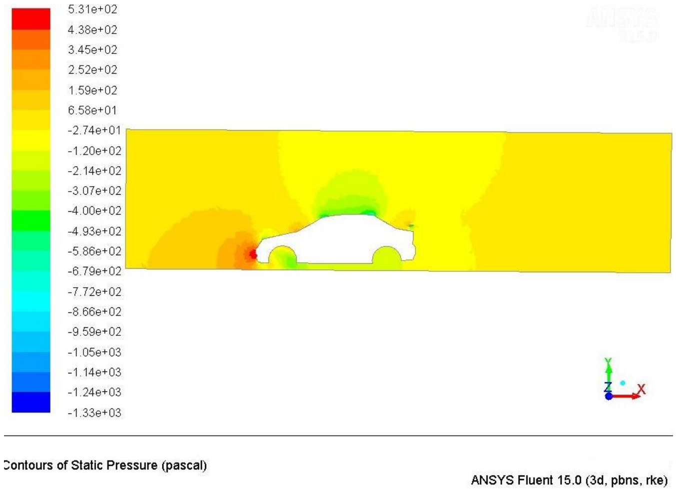

Figure 10: Total Pressure Contour With Rear Spoiler Using Axial Plane

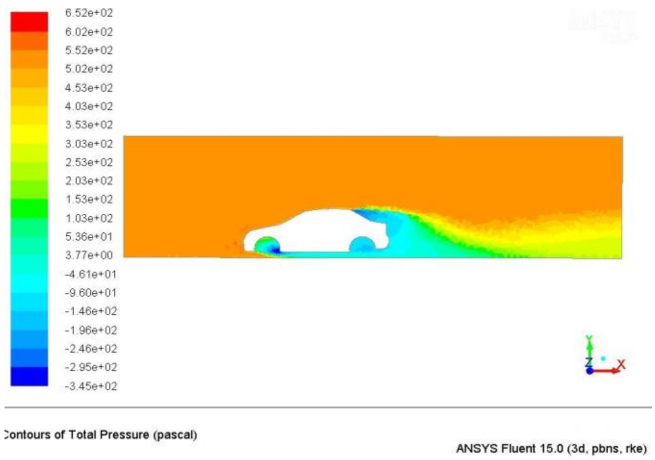

Figure 11: Total Pressure Contour With Top Spoiler Using Axial Plane

5.2.2. Velocity Contours

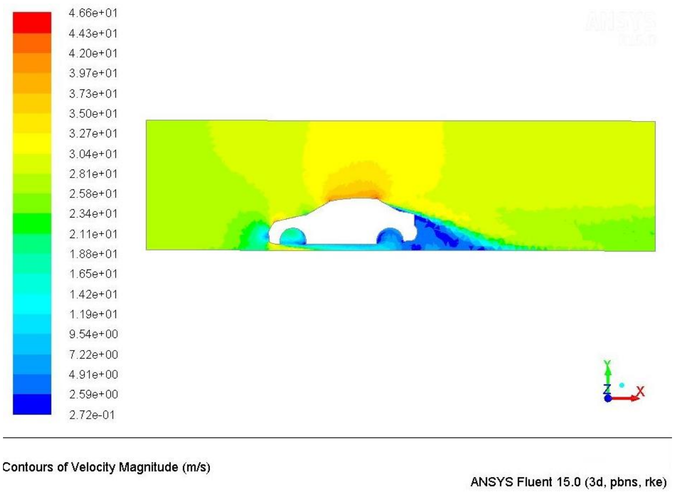

Figure 12: Total Velocity Contour without Spoiler using Axial Plane

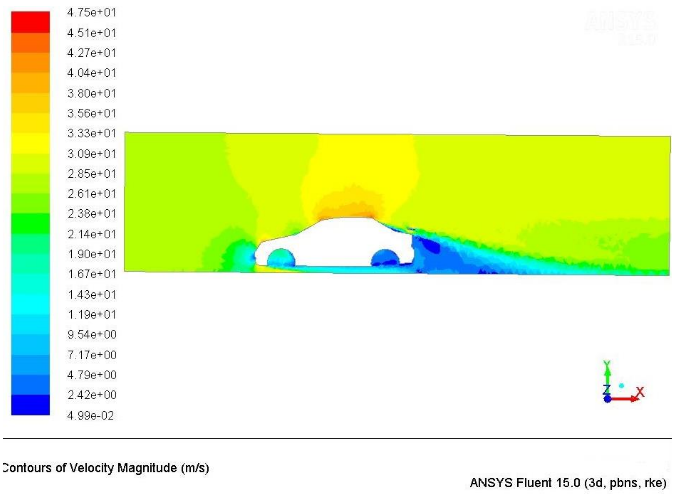

Figure 13: Total Velocity Contour With Rear Spoiler Using Axial Plane

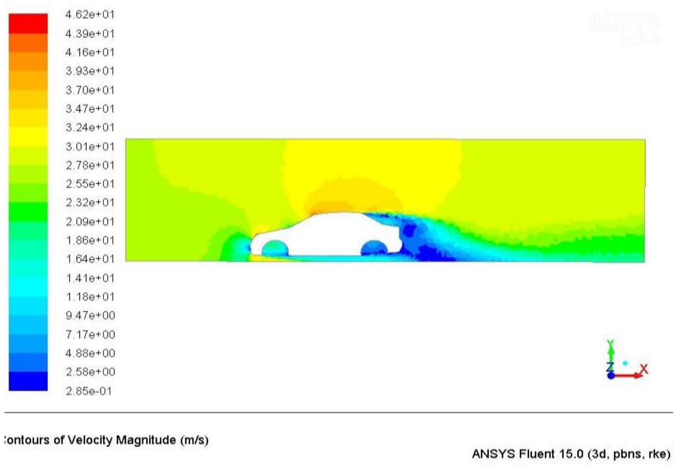

Figure 14: Total Velocity Contour With Top Spoiler Using Axial Plane

6. CONCLUSION

The aerodynamic lift, drag and flow characteristics of a high-speed (~100 Kmph) generic sedan passenger vehicle with a spoiler and without a spoiler situations were numerically investigated.Numerical analysis has showed us that the spoiler design, which was mounted to the rear-end provided more negative lift force than the roof spoiler did but provided less drag reduction.Roof spoiler provided drag reduction but the negative lift force has been increased. It is known that having down force (i.e. negative lift force) .Sedan car with roof Increases tires capability to produce cornering force, Stabilizes vehicle sat high speed, Improves braking performance, Gives better traction, Reduce in lift may lead to reduce of dirt on the rear surface, Reduce in drag leads to maximum speed for a given engine power, compared to rear spoiler sedan car.

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