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MODELING AND AERODYNAMIC SIMULATION OF THE PASSENGER VEHICLE

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Abstract

Today, the vehicle aerodynamics has a significant place in the development of vehicle shape, as well as in increasing competitiveness in the automotive market. Aerodynamics has a big influence on improving the vehicle dynamics, reducing fuel consumption, increasing transverse vehicle stability, and increasing vehicle safety during the braking. The development of computer technology made it possible to detect the defects of a product in the early stages of development. This further aims at achieving a shorter time for creating a new one or modifying an already existing product. The simulation of the air flow effects is presented in the paper, using the ANSYS software package. Furthermore, an overview of the impact of the angle of the windscreen on the loads occurring on the vehicle itself is given, in order to improve the vehicle performance.

Keywords: *shape development, vehicle dynamics, air flow, performance improving.*

1. INTRODUCTION

In a process of designing a more attractive vehicle, manufacturers must first know what customers want. Passenger vehicle is not just a means of transportation, also represents a person's personality. It can be said that design is the key for the success of a vehicle on the market. For this reason, marketing experts spend a lot of time exploring the desires and needs of the market, in terms of design, price, performance, comfort, and many other features. Of course, in addition to all other characteristics, the drag coefficient must not be omitted.

Aerodynamics is a science that deals with the movement of the air currents along the contour surfaces of the obstructed object [1]. The shape of the vehicle affects the dynamic behavior of the vehicle, fuel consumption, increases vehicle stability, increases vehicle safety during braking. How important is the vehicle's aerodynamics can be seen from the fact that it was noticed by the appearance of the first car body, and it became significant with the appearance of engines with larger power that enabled the development of high speeds.

During the vehicle movement, there is a friction of air with outer surface of the vehicle. There are two reasons why there is a friction between moving vehicles and air. The first is that it is almost impossible to make an ideal smooth surface, and the other is the viscosity of the fluid. By a vehicle moving, air is compressed in the front, while in the rear part of the vehicle, there is a dilution of particles [2]. The consequence of this is a frontal impact, where the air is opposing the vehicle's movement.

The evolution of car design through time is shown in *Figure 1*. The idea begins with an aerodynamic shape - a drop and a vehicle that has a similar look [3]. The vehicle's shape like the droplet was not suitable due to low quality roads and low engine power [4]. Then, in the next period, a number of proposals were followed to eliminate the many shortcomings that were found in the first cars. In the 1970s, in the period of the oil crisis, on the basis of the existence relationship between air resistance and vehicle fuel consumption, further attention was focused on reducing the drag coefficient, so that for a period of twenty years the drag coefficient was reduced by 40%.

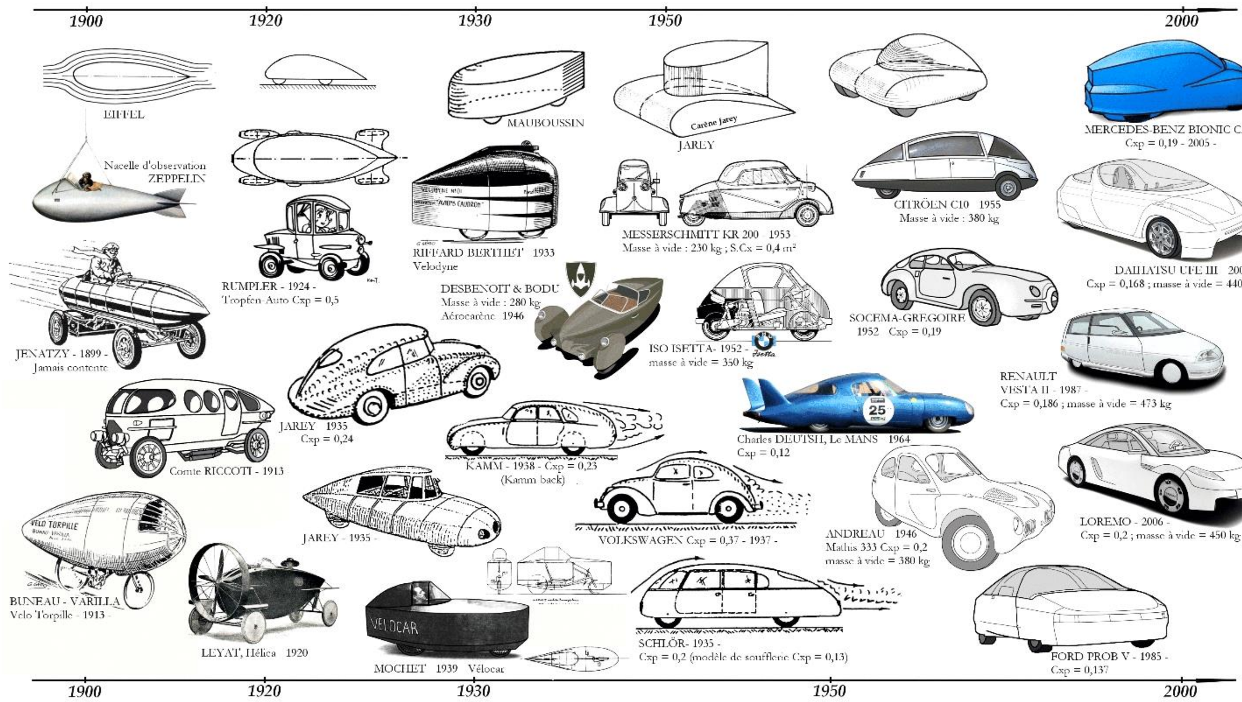

Figure 1 Evolution of car design through time [5]

Today, the technique has advanced considerably, as proved by Parab et al. [6], in addition to aerodynamic tunnels, numerical simulations became very important during the design phase of the prototype of a new vehicle. They have shown, in their research that the obtained results do not deviate largely from the results obtained by the experiment, so that the results can be fully accepted. Because of the great importance of the competitiveness on the market, car manufacturers do not have time to design a completely new car, but make corrections and improvements to existing ones. In this way, they get on time and reduce production costs. This applies not only to cars, but also to other types of vehicles. Yhang et al. [7] quickly created a completely new car design, starting from the sketch, and then they created the 3D model, after which they performed a numerical analysis and obtained the drag coefficient. Ali et al. [8] have found that optimizing the car shape significantly reduces fuel consumption, improves the characteristics of the comfort and provides more favorable driving characteristics. Sharath Kumar and Umesh [9] compared sedans and caravans, where the front of the car is identical, only the difference is in the rear part. It can be concluded that the sedan has a more aerodynamic shape.

With the increasing of car speed, which is the property that is today most attracted by the most customers, there is a problem that the stability of these cars decreases. In order to overcome one such defect, spoilers are installed. Reducing air resistance is also possible by installing a spoiler on the car, as shown by Hu and Wong [10]. In this way, the fuel consumption of cars is lower. Daryakenari et al. [11] compared a number of different spoilers, allowing further determinants, which are the best among them.

The aim of this paper is based on the display of resistances that occurring on the vehicle, as well and determination of the drag coefficient.

2. 2D MODEL DEFFINING OF BOUNDARY CONDITIONS

The main focus of paper is based on the aerodynamics of the vehicle. Before creating the final 3D model, it is necessary to determine how its shape influences on the resistance that occurs when vehicle moving. The analysis will be performed with the 2D model, *Figure 2*. The 2D model was created in the CATIA software package, while the analysis was performed in ANSYS, using the Fluid Flow (Fluent) module. A variable parameter whose influence will be tested during the analysis is the angle of inclination of the windshield, α.
Three different values were selected for angle α: 30º, 33º and 36º.

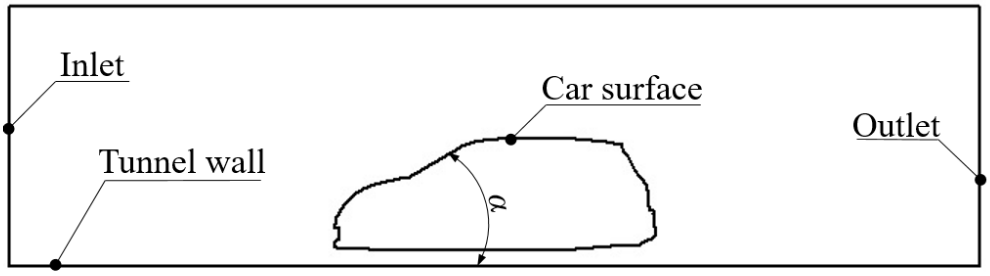

Figure 2 2D model

Regardless of whether it is a 2D or 3D model, it is necessary to define boundary conditions. The environmental condition under which the vehicle is being tested is defined with an air temperature of 27°C. The vehicle's speed is 100 km/h. Turbulent air flow occurs when a vehicle moving, so this is taken into account during the analysis. The air, in this case, is incalculable. The analysis uses the Navier-Stokes equations, and the SIMPLE algorithm is selected.

3. RESULTS

Numerical simulation of aerodynamics has a number of advantages. One of the most important is time saving, as well as the reduced cost of creating a new vehicle model.
The air pressure that occurs around the vehicle contour, when $\alpha = 33°$, is shown in *Figure 3*. The maximum pressure values occur in the front of the vehicle. The reason for this lies in the fact that in this zone of the vehicle, there is compression of air due to the vehicle movement. There are slightly lower pressures in the rear of the vehicle, as the air is thinned. The vehicle with his movement compresses the air in the movement direction. The lowest pressure values are between the bottom of the vehicle and the ground.

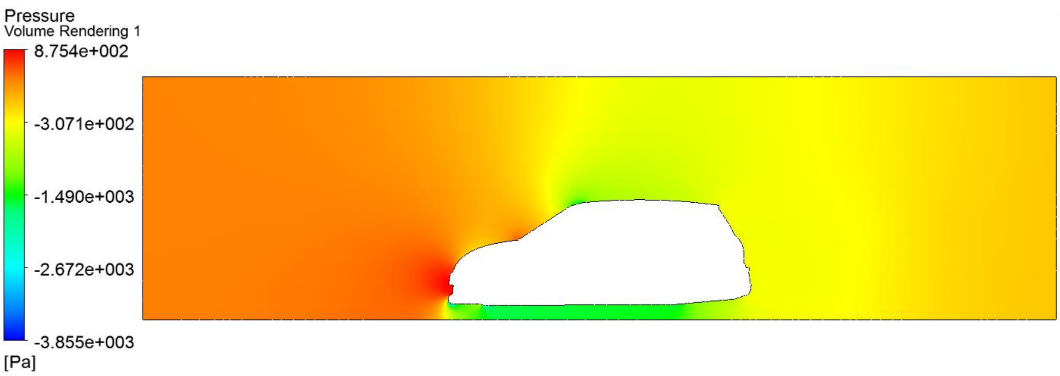

Figure 3 Pressure contour

Changing the angle α, more precisely with its increase, values of maximum pressure that occurs during the vehicle moving under the same boundary conditions of the analysis are reduced.
The display shows the effect of the pressure on the vehicle contour and is given in *Figure 4*, where it can be noticed that the maximum pressure values occur in the bumper area. It is understandable that there are higher air pressures in this zone, because in this way the vehicle has good cooling of the engine. Also, at the transition between the hood and the windshield, there are slightly higher pressures. The reason for this is the very shape of these surfaces, due to which such high pressure values are present.

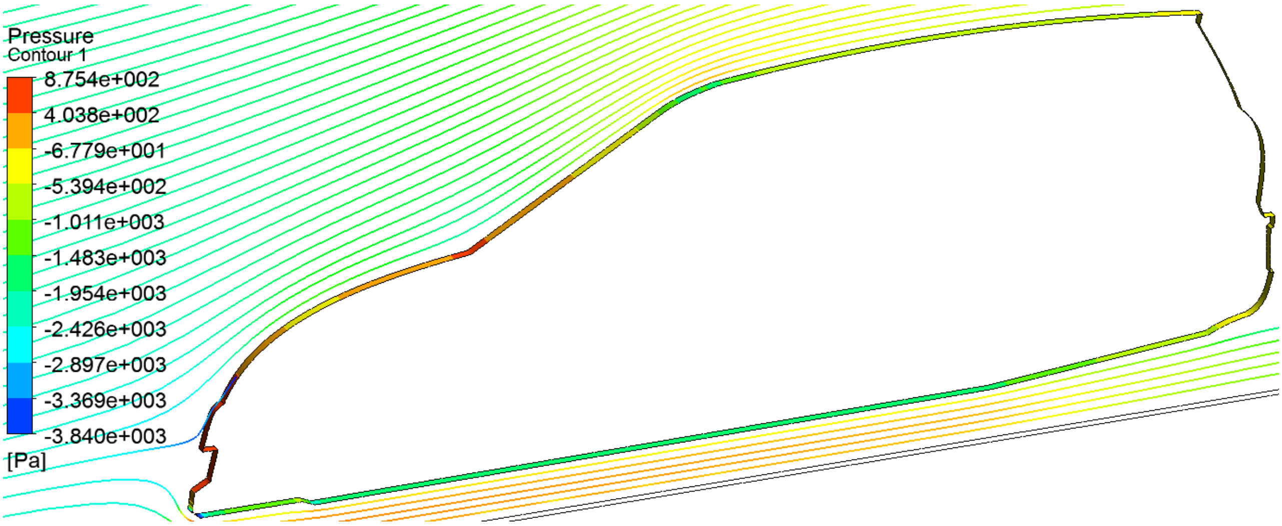

Figure 4 Pressure distribution on the contour of the vehicle and the air flow

Turbulence kinetic energy represents a measure of turbulent flow in the immediate proximity of the vehicle. In this case, turbulence kinetic energy is the result of the air flow and the movement of the vehicle. The values of the turbulent kinetic energy, when $\alpha = 33°$, are shown in *Figure 5*. For the angle $\alpha = 30°$, the kinetic energy is 101.953 J/kg, and for $\alpha = 36°$, it is 101.796 J/kg. Based on the obtained values of turbulence kinetic energy, it can be noticed that there is no clear connection between the change of angle and turbulent kinetic energy. From other authors' research, it was found that the reduction of turbulent kinetic energy is accomplished by implementation of the spoiler.

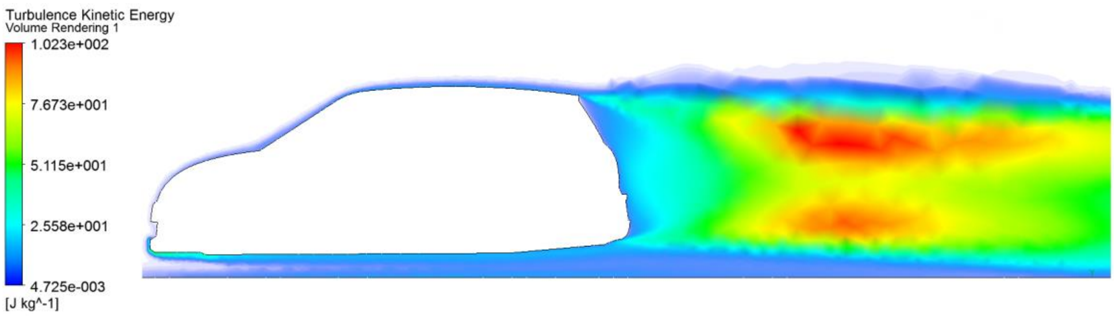

Figure 5 Turbulence kinetic energy

One of the most important indicators of the aerodynamics of the vehicle is the drag coefficient, and the values for the different angles of the windshield inclination are given in *Table 1*. As in the case of turbulence kinetic energy, the same conclusions can be achieved for the drag coefficient. Taking into account that the aerodynamics of the vehicle is a very important parameter, which affects not only the aesthetic form of the car, but also the dynamics of the vehicle. Based on these values, it is necessary to find the optimum value of the incline angle of the windshield and thereby influences the reduction of resistance that occurs during the vehicle movement - air resistance.

Table 1 Drag coefficient in function of angle α

Angle, [˚]	Drag coefficient, [-]
30	0.31438086
33	0.31487155
36	0.31443887

CONCLUSIONS

In this study, the influence of the inclination angle of the windshield on the pressure, turbulence kinetic energy and drag coefficient is shown. With the rise of the inclination angle of the windshield, the pressure is reduced. The minimum values of the turbulence kinetic energy is obtained at an angle of 36º, which corresponds to the maximum angle in this analysis. While the smallest value of the drag coefficient occurs at angle of 30º - the minimum angle in this analysis. Using CFD numerical analysis provides an efficient and fast way to check the aerodynamics of the vehicle.
Future research should be based on a further reduction of a drag coefficient. Further study would be based on varying other vehicle parameters that also affect the drag coefficient. Furthermore, in addition to the parameters of the vehicle geometry, it is necessary to show the influence of the spoiler mounting. In addition to all this, the analysis should be done on a 3D model.

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