Numeric analysis of airflow around the body of the Silesian Greenpower vehicle

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Abstract. Numerical analysis of drag values of an electric race car's body. Silesian Greenpower is a student organization specializing in electric race car design. One of the most important issues during the design is reducing the vehicle drag to minimum and is done, mainly, by designing a streamline car body. The aim of this work was to design two electric cars bodies with different shape in Siemens NX CAD software, next a finite elements mesh was created and implemented into the ANSYS Workbench 16.1 software. Afterwards an aerodynamic analysis was carried out, using the finite element method (FEM). Simulations and calculations have been performed in ANSYS Fluent: CFD Simulation software. Computer simulation allowed to visualize the distribution of air pressure on and around car, the air velocity distribution around the car and aerodynamics streamline trajectory. The results of analysis were used to determine the drag values of electric car and determine points of the highest drag. In conclusion car body representing lower drag was appointed. The work includes theoretical introduction, containing information about finite element method, ANSYS and Siemens NX software and also basic aerodynamics laws.

1 Introduction

Silesian Greenpower is a project realised by students of Silesian University of Technology. The project focuses on designing and manufacturing electric racing vehicles which participate in international Greenpower formula races.

The geometric shape of the cars is inspired by already existing technical solutions as well as brand new solutions. In the designing process a lot of new innovative solutions are introduced to improve aerodynamic properties of the vehicle body.

The following publication concerns numeric analysis in terms of airflow and its stream around the race car shown in graphic form.

Teams constructing electric vehicles of Greenpower formula are trying to minimize drag which causes energy loss, at every step. The aerodynamic resistance of the car has the largest percentage share in the overall drag acting on the vehicle.

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Fig. 1. Silesian Greenpower team.

Using ANSYS Fluent software it is possible to determine the vehicle drag in the design phase, and, basing on the simulations-modifications to the geometric shape of the car can be introduced. Carried out calculations have been a comparative analysis of aerodynamic properties of both models.

2 Studies

The project starts with designing the model in CAD software. ANSYS Workbench allows to easily transport CAD model to ANSYS software.

The first step of geometric edition was creating the influence zone, where the vehicle was installed. This zone reflects the real environment around the car. Additionally, the car moves on the surface, which also has to be taken into account. Therefore, coordinate system has been made, which define the symmetry of the car and intersection lines where wheels meet the surface.

In order to yield more accurate results, additional area around the car has been introduced. This area has mesh of higher density in relation to other areas around the car. Thanks to this, results can reflect reality much more accurate.

On geometric models with mesh imposed the boundary layer is notably seen. This layer is extremely important for aerodynamic research because it is the transition border from the lower airspeed to the highest.

The number of elements in the mesh of the model with the sharp beak is 13,065,067 with 2,384,922 nodes, whereas in the model of NACA profile car there are 13,286,671 elements and 25,18,034 nodes. Node count is directly related to the number of grid elements. Most commonly they are the corner points of finite elements. The nodes were automatically generated by the ANSYS Workbench software. Grid parameters determine the node count. Node counts between the two vehicles differ in a significant way because of the shape of the analyzed models that is different number of curves making up the planes of car body [1-2]. Figure 2 represents the number of curves.

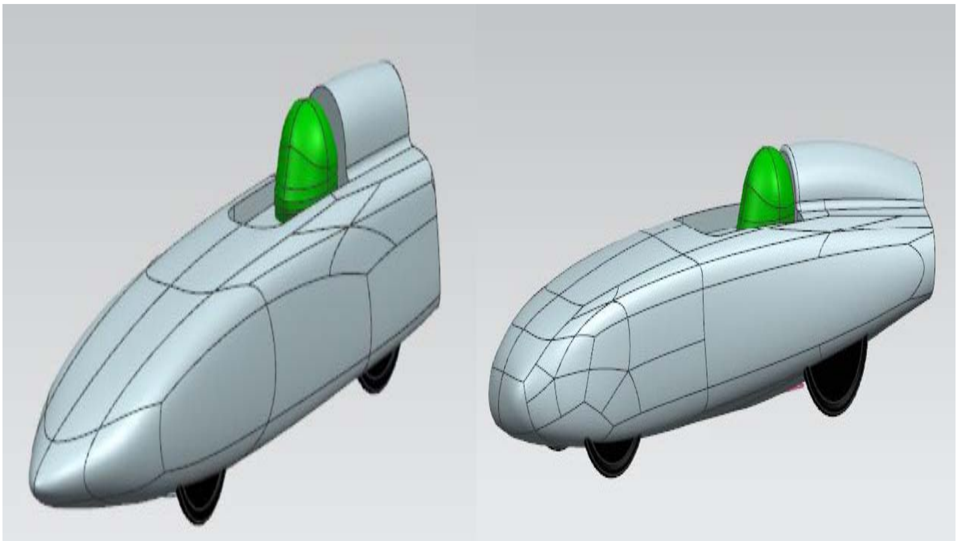

Fig. 2. Comparison of model curves.

The boundary layer close to the contact of the body and influence zone has been shown in Figure 3.

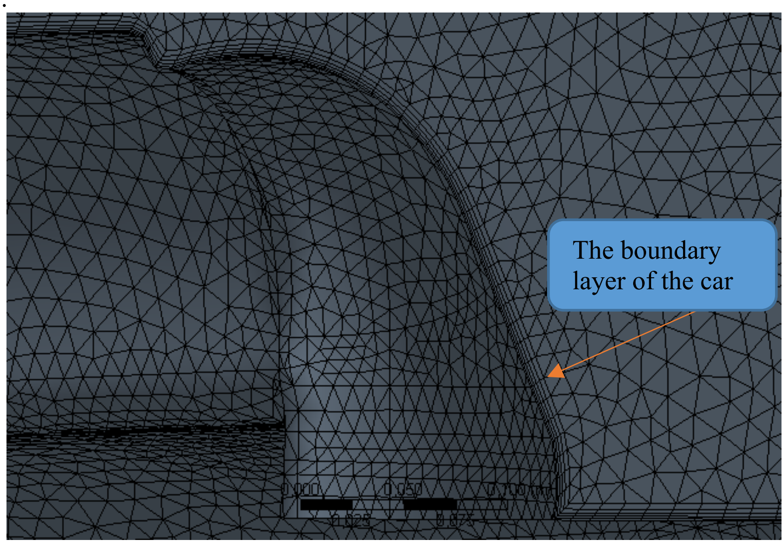

Fig. 3. The boundary layer between first influence zone and drivers helmet.

Both models have been inspected under the same conditions, with a constant air speed of 17 [m/s]. Simulations were made in compliance with standards applicable in automotive industry, therefore for the C2-Epsilon parameter the value 1.9 was used in order to reflect real conditions as much as possible. Whereas for the model of turbulence the value used was k-ε [3].

Figure 4 represents the distribution of the airspeed around the body of the car. Areas, where the speed is the lowest, were marked blue. Blue area formed behind the car is called the virtual tail. Thanks to an appliance of this occurrence the total drag of the vehicle does not increase in relation to the total drag of the body. This phenomenon is called Kammback effect. With colour red areas where the airspeed is the highest were marked, which is caused by lower air pressure value, because of the stream overlapping effect.

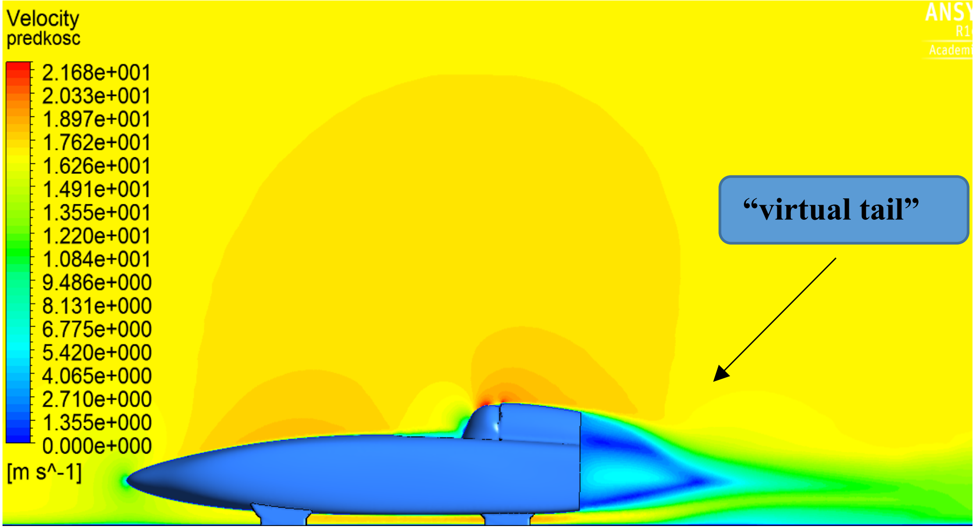

Fig. 4. Speed distribution around the car with the sharp beak at speed [17 m/s].

Figure 5 also represents speed distribution around the body of the car. In this case, the model was designed according to NACA profile. This car also has the so-called virtual tail.

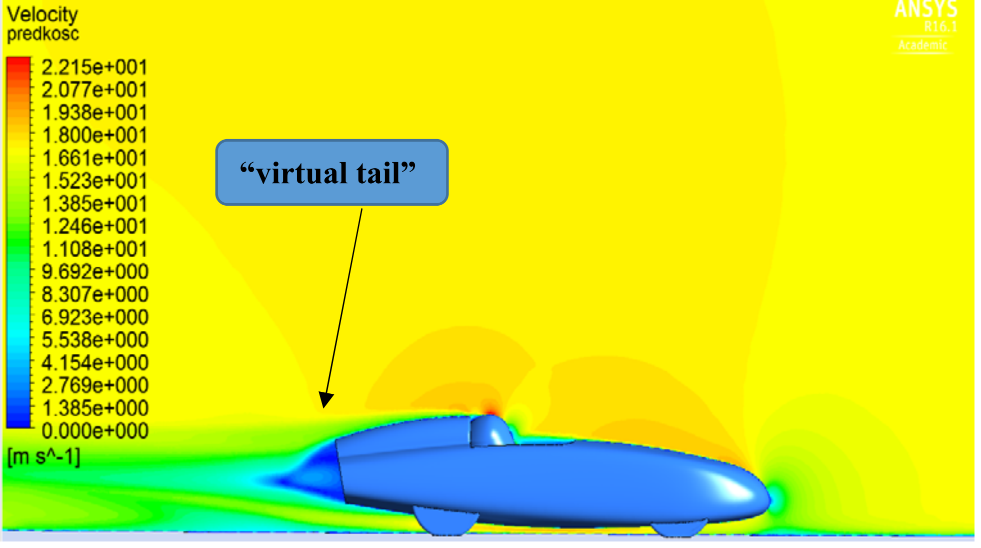

Fig. 5. Speed distribution around the car with NACA profile at speed [17 m/s].

In both cases, white marked spots are areas where the stream has been detached from the body of the car. The redder area is an area where the speed of the air is higher. The highest speed of the air is below the body, and it is caused by under pressure.

The course of the air stream around the car with the sharp beak has been presented in Figure 6.

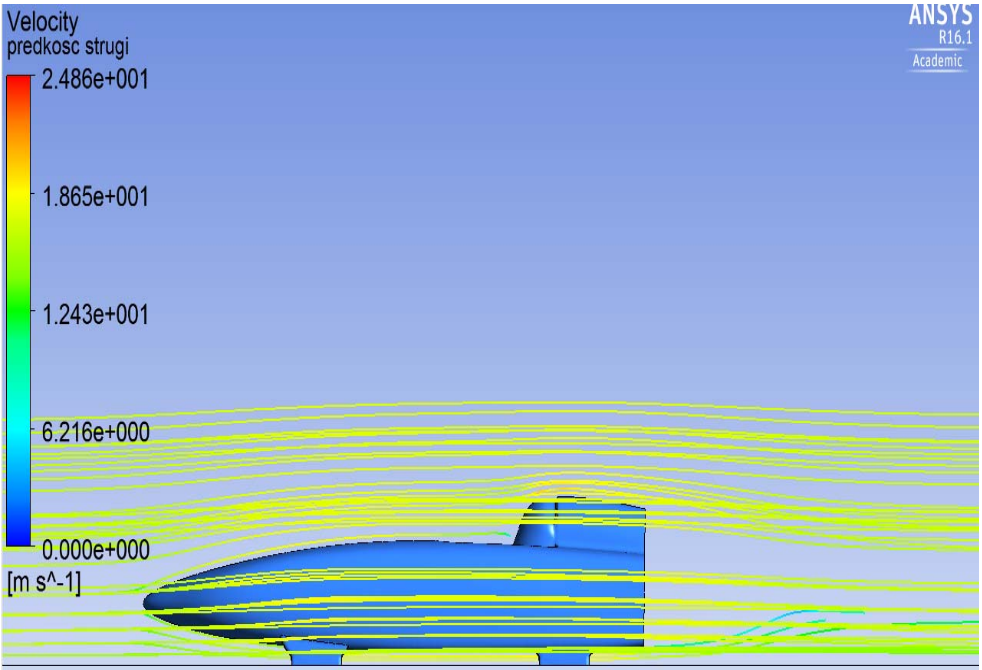

Fig. 6. The course of the air stream around the car with the sharp beak at speed [17 m/s].

Thanks to such visualizations, it can be foreseen how the car would act on the race track, and the body of the car can be modified in order to improve aerodynamic properties.

The course of the air stream for the car with a geometric form designed according to NACA profile has been shown in Figure 7.

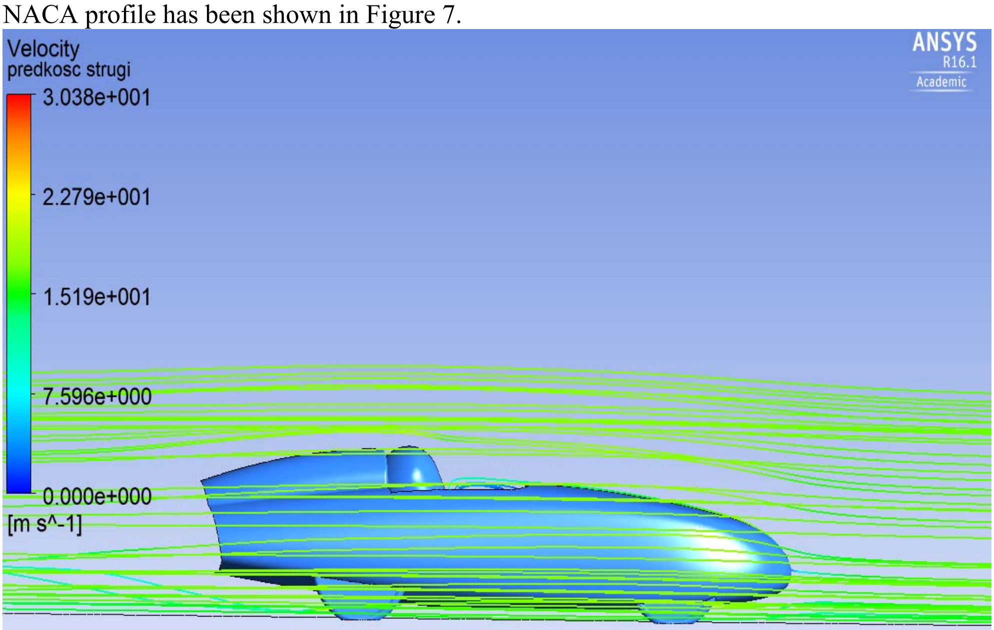

Fig. 7. The course of the air stream around the car with NACA profile at the speed [17 m/s].

The Finite Elements Method analysis has shown which of the cars possess lower aerodynamic drag relying on the designation of aerodynamic resistance (C_x factor), and definition of the course of air stream. Also, research has proved the existence of the phenomenon called virtual tail marked in the figures. The car designed according to NACA profile represents lower ability to form the virtual tail basing on the Kammback effect.

Table 1. Results of aerodynamic simulation of C_x factor and aerodynamic forces acting on the car.

Model	C_x	F_x
Sharp beak car	0,2057	11,97
NACA profile car	0,2209	13,23

3 Conclusions

As a result of the carried out research, it was established that the case of a model with the sharp beak represented a lower aerodynamic resistance. The results have been shown in Table 1.

An additional aspect of the research is the possibility of visualization of the air flow course, as well as the velocity of the air around the car.

Thanks to ANSYS software aerodynamic resistance of the cars can be determined. In effect, they can still be modernized during the design phase, what results in victories of the team in Greenpower racing formula series.

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