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**Jakub KIEDROWSKI[1], Grzegorz JENDRO[2], Arkadiusz KAMIŃSKI[3], Paweł FABIŚ[4]**

# AERODYNAMICS PACKAGE FOR FORMULA STUDENT CAR WT-02

**Summary.** This paper is a summary of the design and workmanship of the aero package vehicle Formula Student. Simulation research projects of the aerodynamic system were conducted. The article proposes different variants of the aero wings and conducted simulation studies of construction. The aerodynamics system impact on strength and reliability of selected models was determined.
**Keywords:** Formula Student, aero pack, MES, simulation

## 1. INTRODUCTION

Formula Student (FS) is an international competition between teams of universities and technical faculties from around the world organised in Europe by IMechE. The idea behind the competition is to design and execute a racing vehicle in accordance with the rules of the competition. The creation of the team finished the car in given time and in line with the need to gain the knowledge, discipline, cooperation, foresight, and often compromises. Experience and knowledge gained in such circumstances are invaluable and an important part of training top-

[1] "Silesia Automotive". Student Science Club. Faculty of Transport Silesian University of Technology Krasinskiego 8 Street. 40-019 Katowice, Poland. Email: jakubkiedrowski@wp.pl
[2] "Silesia Automotive". Student Science Club. Faculty of Transport Silesian University of Technology Krasinskiego 8 Street. 40-019 Katowice, Poland. Email: jakubkiedrowski@wp.pl
[3] "Silesia Automotive". Student Science Club. Faculty of Transport Silesian University of Technology Krasinskiego 8 Street. 40-019 Katowice, Poland. Email: arkadiusz.kaminski @gmail.com
[4] Faculty of Transport Silesian University of Technology Krasinskiego 8 Street. 40-019 Katowice, Poland. Email: pawel.fabis@polsl.pl. ORCID: https://orcid.org/0000-0001-6087-6467

notch engineers. Undoubtedly, this is also a chance to test their skills in the real world, under the pressure of time and project requirements. Of importance is not only the designed maximum speed of the car but the balance between a number of important elements to be taken into speed, economy of operation, aesthetics, functionality and safety. The victory in the competition is only for those teams that are able to give a complete project and get it for the highest number of points. With the FS, students have the chance to establish contacts with the local industry, and the industry has the opportunity to support the development of its potential future executives. The basis for the formula student undoubtedly is the idea of supporting the development of technical ideas. It shows the importance of creating technical universities. Engineering studies and profession play a huge role in human development, therefore, are of great value to society.

## 2. VEHICLE AERODYNAMICS

During its movement, a car vehicle is loaded with forces from flowing air. This air is used as a cooling medium for the engine element and as an element improving for the vehicle's behaviour. Modern road vehicles use the air washing over it to improve the stability of the vehicle behaviour in curves. Especially in racing vehicles, so-called aerodynamic packages allows the increase of the pressure force of the vehicle on the surface, which allows obtaining higher speeds at bends [1]. General assumptions of the basics of aerodynamics in relation to motor vehicles are presented in the paper Fuller et al. [2]. The work applies to road vehicles, but the assumptions also apply to racing vehicles. Methods of designing and making aerodynamic packages for high-performance cars and racing cars are presented in [3 and 4]. The works presented ways of designing racing cars, the impact of shape profiles on their downforce.

## 3. AERO PACKAGE FOR THE FORMULA STUDENT CAR

The object of the research is a vehicle racing class Formula Student WT-02 equipped with a four-cylinder, four-stroke SI engine with a capacity of 600 cm$^3$. Originally, this engine was powered by a carbureted system, however, in the course of adapting the engine to the vehicle, it was converted to multi-point injection system.

During the project construction, in order to increase the dynamic qualities of the vehicle, a charging system was applied using a turbocharger. These engine modifications allowed to obtain 97 kW of power – a sufficient amount to overcome the additional drag from the aerodynamics package.

The car was designed without any aerodynamics systems. During the season, after race results analysis, the team took the decision to design the aerodynamical systems. Systems should have front and rear wings and side aileron which improve air flow to the cooling system and intercooler. These are presented in Fig. 1.

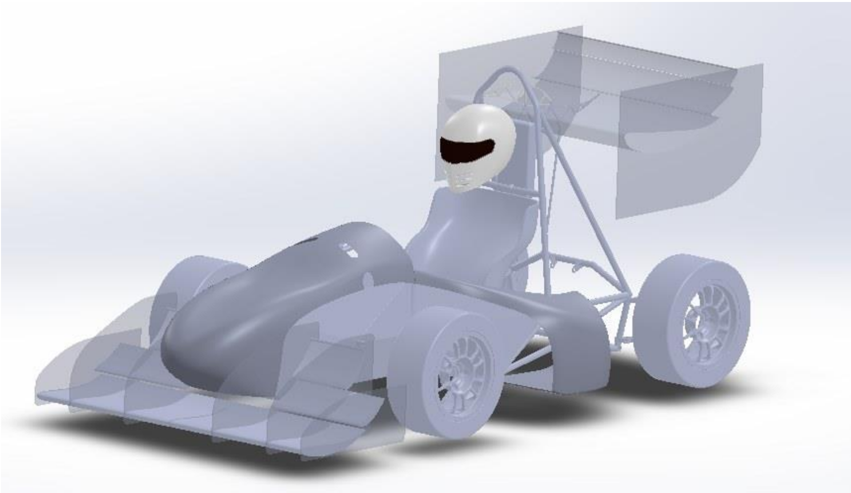

Fig. 1. View of car WT-02 with aerodynamical system

## 4. PROJECT OF THE AERODYNAMICAL SYSTEM

Angle of attack $\alpha$ is an angle between the chord line of an airfoil and the direction of the fluid stream. According to literature, the lift coefficient $C_L$ increases with increase of $\alpha$. The peak for $C_L$ is obtained for $\alpha = 10 \div 15°$. Three airflow simulations were performed respectively for angles 5°, 10°, 15° and for each one of them, pressure and velocity contours were received, which are presented in Fig. 2-4. The simulation was made for the bottom airfoil of the rear wing.

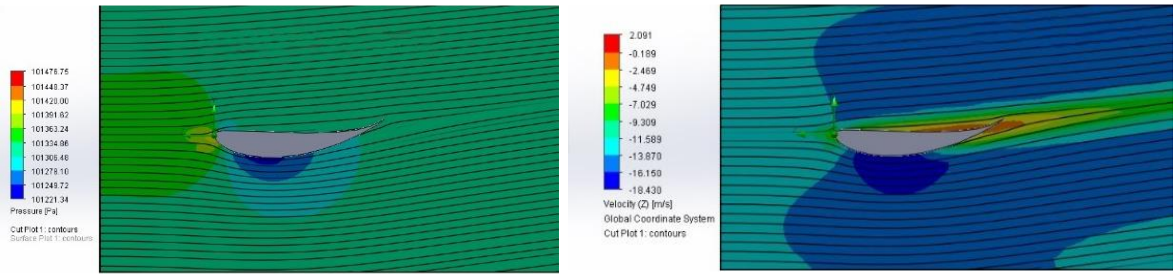


Fig. 2. Pressure and velocity contours for $\alpha = 5°$

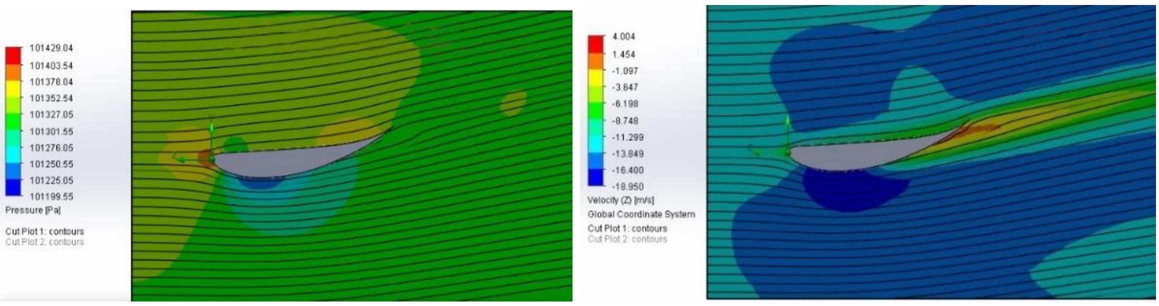


Fig. 3. Pressure and velocity contours for $\alpha = 10°$

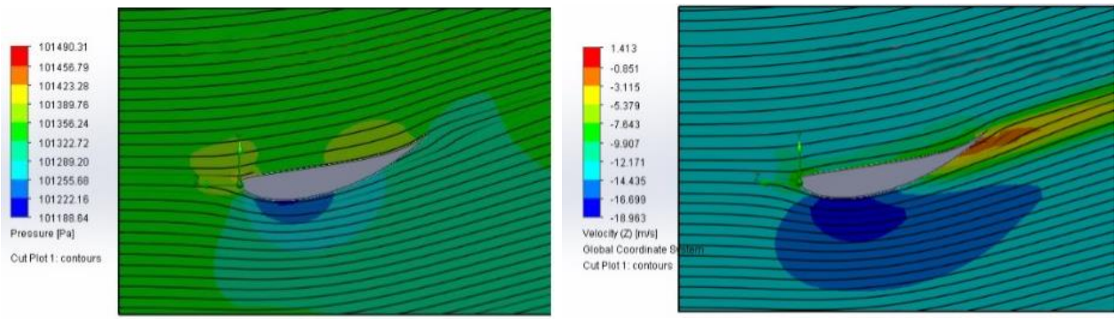


Fig. 4. Pressure and velocity contours for α = 15°

It follows from the above that for angles 10° and 15° under- and overpressure zones are located in similar places relative to the surface of the airfoil and the pressure values are comparable. For 5° angle of attack, the airfoil produces comparable underpressure to other settings but an explicit overpressure zone is not created, therefore, this is not the most favourable setting for a single element wing. However, the rear aerodynamic package is a three-element wing, hence, for better cooperation between airfoils arnd for guiding a part of the flow to the diffuser, the 5° angle of attack was applied. The analysis for the rear wing is presented later.

Front aerodynamic package consists of three airfoils, which are of various sizes and inclination. The front wing design, in order to generate maximum downforce, requires utilisation of utmost area, which is indirectly restricted by FSAE rules. Applied arrangement and sizes of each airfoil are the results of observations of similar constructions and many time-consuming airflow simulations.

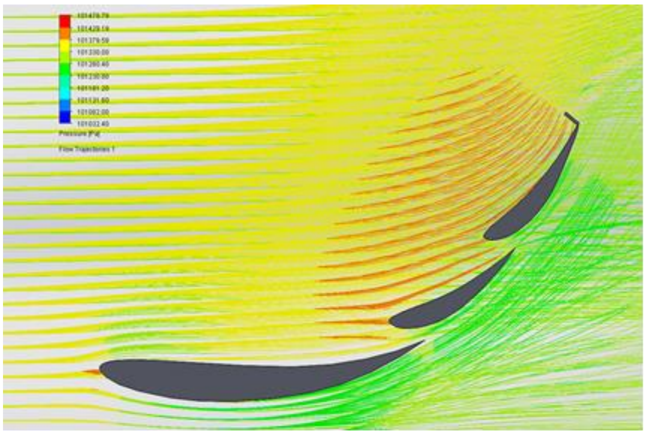

Fig. 5. Pressure contour for front wing package

From Fig. 5, it follows that the greatest overpressure is generated over two most leaning airfoils. The underpressure zone which is forming over the bottom airfoil is unfavourable (this is the result of low angle of attack) but due to this setting, a part of airflow is guided beyond the wing (in direction to the diffuser) and also attached flow is obtained, which accumulates underpressure underneath the wing. The stationary flap on the upper airfoil cumulates overpressure above the wing that results in increasing downforce while maintaining the size of the wing.

Rear aerodynamic package, as well as front package, contains three airfoils at various sizes and inclination. For the same reason as before, the bottom airfoil has a low angle of attack (0°). However, the rear wing is greater than the front wing because it is less spatially restricted and higher downforce is preferred on the drive axle.

Fig. 6 presents the simulation of airflow for both wings assembled to the vehicle. The streams from the front wing are directed on the way to the rear wing to increase its efficiency.

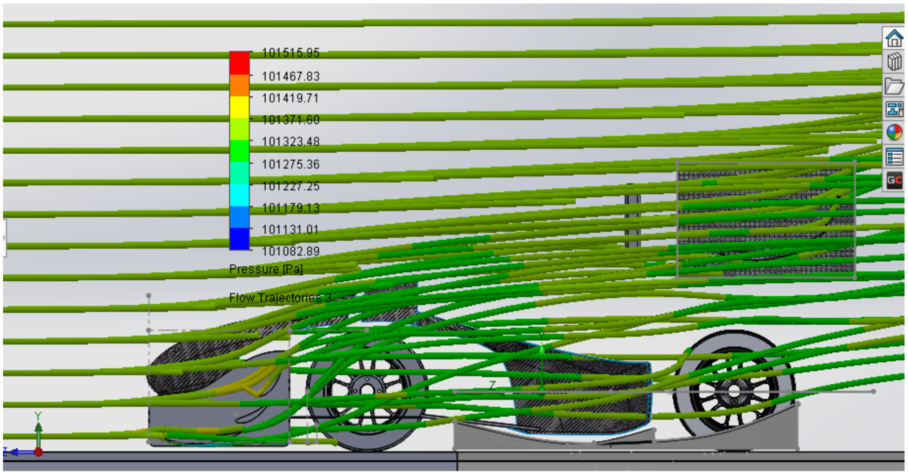


Fig. 6. Vehicle flow simulation

The total downforce deriving from the front and rear wing were calculated. Downforce is a function of vehicle (airflow) velocity and it increases exponentially. WT-02 car can maximally reach around 690 N of downforce at 100 kph. The D(v) graph is presented in Fig. 7.

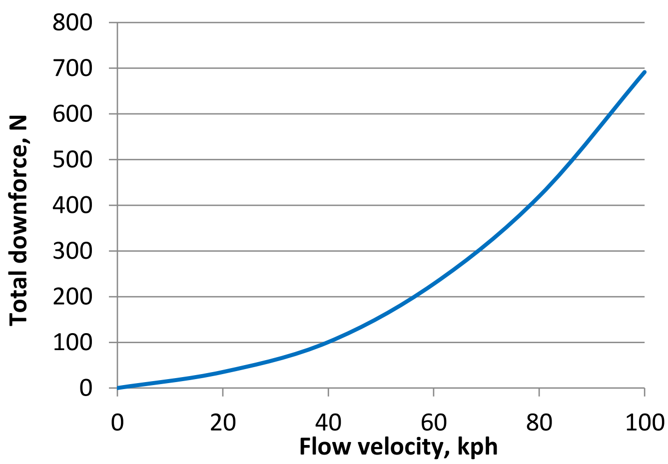


Fig. 7. Downforce vs. flow velocity

## 5. CONCLUSIONS

The study simulations of airflows provided significant information about the influence of airfoils shape and inclination to total achievable downforce. This research leads to the following conclusions:

1. The increase in inclination of a single airfoil affects in increasing downforce but it has to be considered under the cooperation between airfoils on the wing, which is a major issue.
2. To achieve greater amounts of downforce, an aero package should be designed simultaneously with the frame. In the discussed car, this was not done and there was no reasonable possibility to assembly a diffuser.
3. Even though the aero package was designed after constricting the vehicle, 150-200 N of downforce was achieved in Endurance average speeds, which does not stand out from other Formula Student vehicles performance.

It seems reasonable to continue the research for the optimisation of the aero package designand to perform tests on models in wind tunnel.

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