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# THE INFLUENCE OF THE CROSSWIND ON THE LIFT COEFFICIENT, VEHICLE STABILITY AND SAFETY

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**Abstract:** The unadjusted speed of the vehicle, as well as the influence of the lateral wind, are one of causers of traffic accidents. Affected by lateral wind, vehicles have tendency of lateral sliding or drifting, which further affects on the stability during the vehicle control. The aim of this paper is to show, how the lateral wind, as well as the angle of direction of lateral wind, influence on the change of the lift force. Were conducted three virtual experiments, when lateral wind don't exist, and when it acts on the vehicle under angles 45° and 90° with the speed of 25 km/h. The increment of the lift force leads to the disturbance of stable movement of the vehicle in given exploitation conditions. By increment of the wind acting angle, when the wind don't exist and when it acts on the vehicle under angle 90°, the lift force grows approximately 3.6 times, in respect to the case when lateral wind don't exist, that is, when the vehicle is in the peaceful environment without wind.
**Keywords:** vehicle, stability, safety, lift force, lateral wind

## 1. INTRODUCTION

During the vehicle drive, appears the lift force, which actually represents the vertical component of the air resistance, which tends to reduce the pressure between the contact of the vehicle tyres and road. This causes the reduced steerability on the steering axle, while on the drive axle reduces the drive force. All depending from the distribution of the lift force, on front and rear axle, the lift force will cause the vehicle pitch [1]. Depending from the vehicle tendency of lifting, during the drive with higher speeds, the lift force can influence on the maintaining of straight–line driving [2]. Besides that, it makes the vehicle more sensitive to the crosswind. The lift force, has the greatest influence, during the drive with higher speeds, what is characteristic for sport cars.

The crosswind can influence on the vehicle safety in the traffic that is on the appearance of traffic accidents, which influence increases with the increment of the vehicle speed, as well as with the increment of the speed of the crosswind [3, 4]. However, to the greater disturbance of the vehicle stability comes, as well and during the drive with lower speeds, if the acting angle of the crosswind is greater. The crosswind can be present on the viaducts, bridges, or during overtaking large trucks, during driving out of the forested areas, and when the vehicle finds in such situations, can come to it lateral sliding [5], rotation around the vertical axis [6], and even to the roll–over [7], Figure 1.

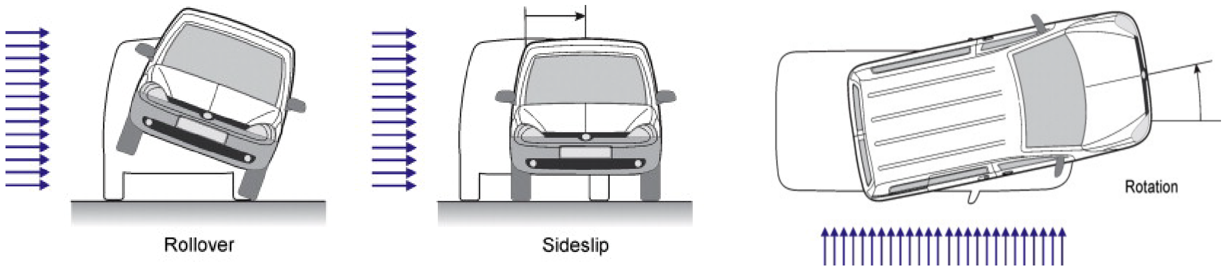


Figure 1. The influence of the crosswind on the vehicle [6]

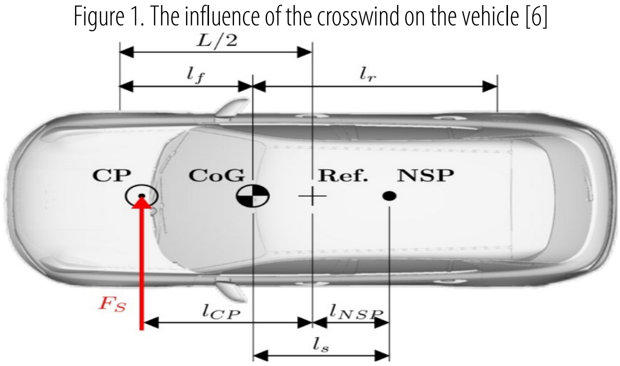


Figure 2. The position of the pressure centre, gravity centre, reference point and neutral point on the vehicle [8]

The great number of researches is based on findings, which are the key factors, which can reduce the sensitivity on the crosswind. By increment of the vehicle mass, wheelbase, the inertial moment of lateral


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turn of, can be achieve convenient influence on the vehicle stability [8]. Also, and the shape of the rear side of the vehicle influences on the vehicle stability [9]. Besides the shape of the rear side of the vehicle, influence have and the vehicle length during the turning of, because with the increment of the length, comes to the increment of the lift force [10]. Also, and the correct adjustment of the vehicle suspension, can improve the vehicle stability in the driving conditions, where on the vehicle acts crosswind. The position of the aerodynamic centre of pressure (CP), in respect to the centre of gravity (CoG), and neutral steering point (NSP) of steering, are crucial for the projecting of such vehicle, which will be stable in the conditions with crosswind [11, 12], Figure 2. While the reference point is on the middle, between the CoG and NSP, that is, on the middle of the wheelbase.

The subject of this research is based on the determination of the influence of the crosswind on the vehicle stability, as well as, how the increment of the angle with which crosswind acts on the vehicle, influences on the vehicle lift coefficient, as well as on the lift coefficient of front and rear axle

## 2. THREE–DIMENSIONAL MODEL AND BOUNDARY CONDITIONS

The analysis of the vehicle stability for the different conditions of crosswind acting, as well as for the case when the crosswind don't exist, will be performed in Ansys software package, Fluid Flow CFX module. The first necessary step is to create the model of the vehicle. Vehicle was created in its real size, and as such, it was used for the analysis, Figure 3. The next step covers the defining of the space around the vehicle, and after that the definition of the finite elements mesh. The finite element mesh is defined as such, that the smallest elements are along the surface of the vehicle, while the element size rises with increment of the distance from the surface of the vehicle, Figure 4. The next step is the defining of the boundary conditions – input parameters. Input parameters are divided in two groups, and that:

— The characteristics of the environment air, and
— The exploitational characteristics of the vehicle.

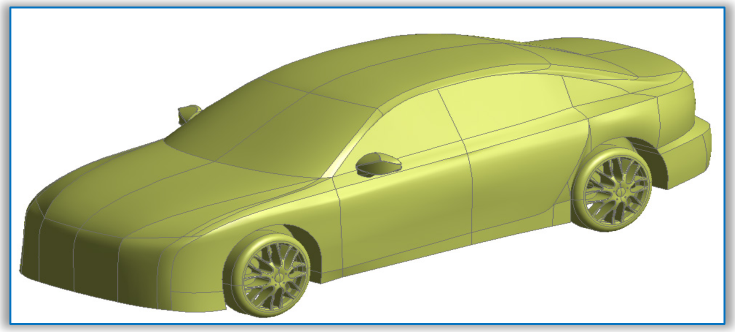

Figure 3. 3D model of the vehicle

Within the air characteristics were defined the ambient pressure ( $p=101325$ Pa), ambient temperature ( $T=25$ °C) and air density ( $\rho=1.225$ kg/m³). While within the vehicle exploitation characteristics were defined vehicle speed, which amounts $v=33.33$ m/s, as well as the speed and direction of crosswind, if exist. In order to simplify the analysis, the wheels of the vehicle do not rotate. The value of turbulences is not defined, but instead is used Low (Intensity=1%).

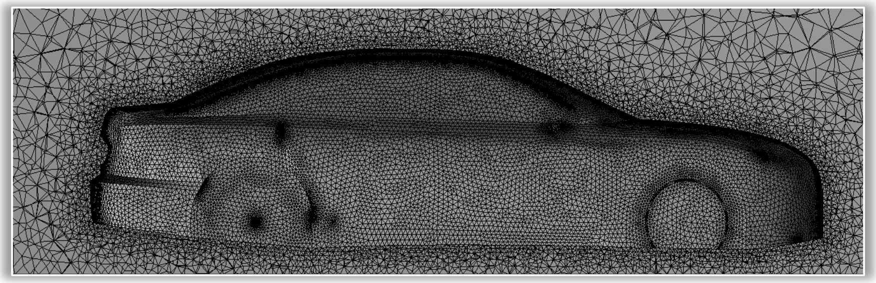

Figure 4. The mesh

In the paper will be performed three analyses, and that:

1. When the vehicle is driven in the peaceful environment, without the crosswind, and the vehicle speed is 33.33 m/s;
2. The case when the vehicle speed is 33.33 m/s, and on it acts crosswind under angle of 45°, which speed is 6.94 m/s (Figure 5), and


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3. The case when the vehicle speed is 33.33 m/s, and on it acts crosswind under angle of 90°, which speed is 6.94 m/s (Figure 5).

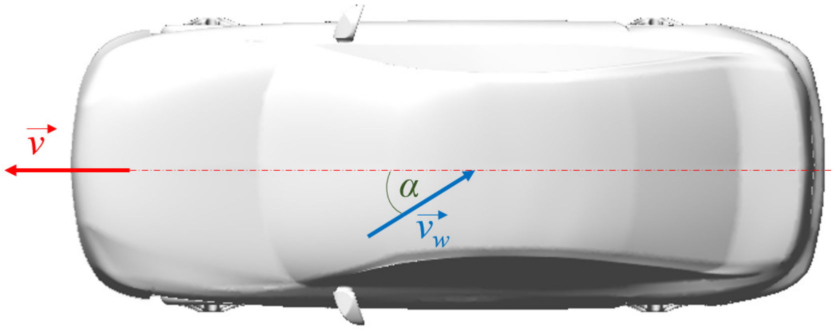


Figure 5. Defining of the speed and direction for the vehicle and the wind

## 3. RESULTS AND DISCUSSION

No matter if the vehicle is driven in the peaceful environment, or in the environment where on it acts wind, it comes to the appearance of vortex, behind the rear side of the vehicle, Figure 6. In the case, when on the vehicle acts the wind, it comes to the greater air vortexes, than in case, when the wind doesn't exist. Also, it can conclude, that with the increment of the wind acting angle, increase and vortex behind the vehicle, Figure 6. If observe the vehicle from the top side (Figure 6), it can see, that in the case when the crosswind acts on the vehicle, it comes to the interweaving of vortex streamlines, that is, it comes to the trespass of streamlines from left side to the right, and vice versa. While in the case, when the vehicle is in the environment without wind, the behaviour of vortex streamlines is almost identical, in respect to the middle plane.

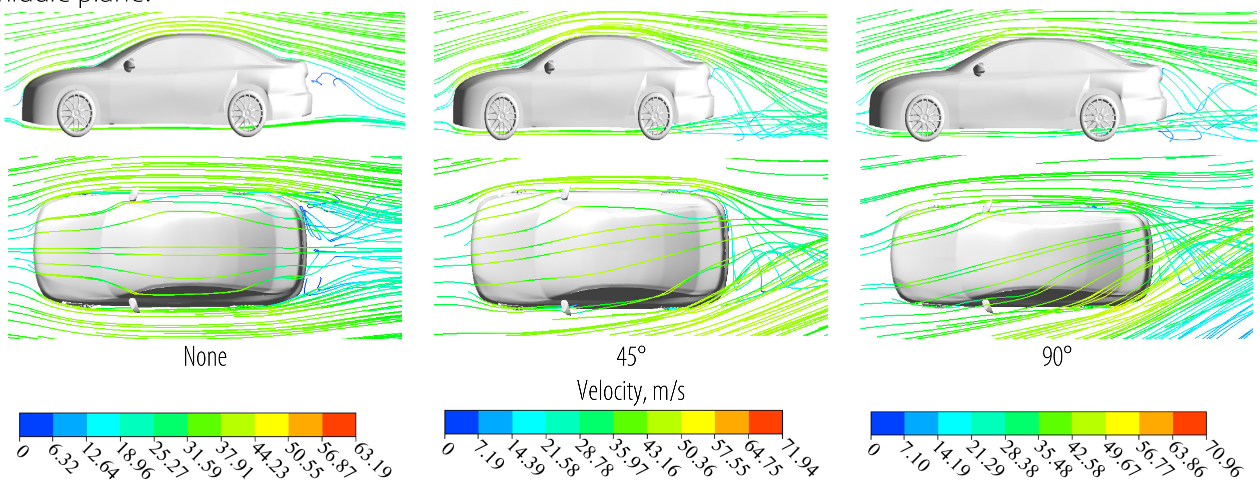


Figure 6. The path and speed of the air around the vehicle

In Table 1, illustratively is shown the speed of the air around the vehicle in defined planes (see Table 1). The null plane (0–0), represents the middle plane of the vehicle. When on the vehicle don't acts wind, behind the vehicle, at the height of the vehicle trunk, don't exist air movement, while in the cases when on the vehicle acts crosswind, this phenomena moves down, beyond the vehicle, which further causes the reduced lift on the rear axle, and increased lift on the front, and by this causes decreased steerability, Table 1. This will be later confirmed and by analysis of lift coefficients for the front and rear axle. By observing the vehicle for the case without crosswind, for planes *a* and *c* (which are at the same distance from middle plane, and that 0.5 m), the behaviour of air flow is almost the same. The same applies and for planes *d* and *b*, which distance from the middle plane is 1.2 m. However, this is not the case, when on the vehicle acts crosswind. For the case, when the acting angle of the crosswind is 45°, in the plane a behind the rear end of the vehicle, comes to the greater drop of the air speed, than in plane c. While, above the vehicle, the air speed is greater for the plane a, than for the plane c. In the plane b, at the side where acts the wind, comes to greeter air speeds, and this is not the case for the plane d. Which further can cause the vehicle instability, as well as its drift, during some sudden manoeuvre. The same behaviour can be noticed and for the case when the acting angle of the wind is 90°.

The highest values of the pressure were recorder for the case without the crosswind, that is when the vehicle is driven in peaceful environment, and it appears on the frontal surface of the vehicle, which first


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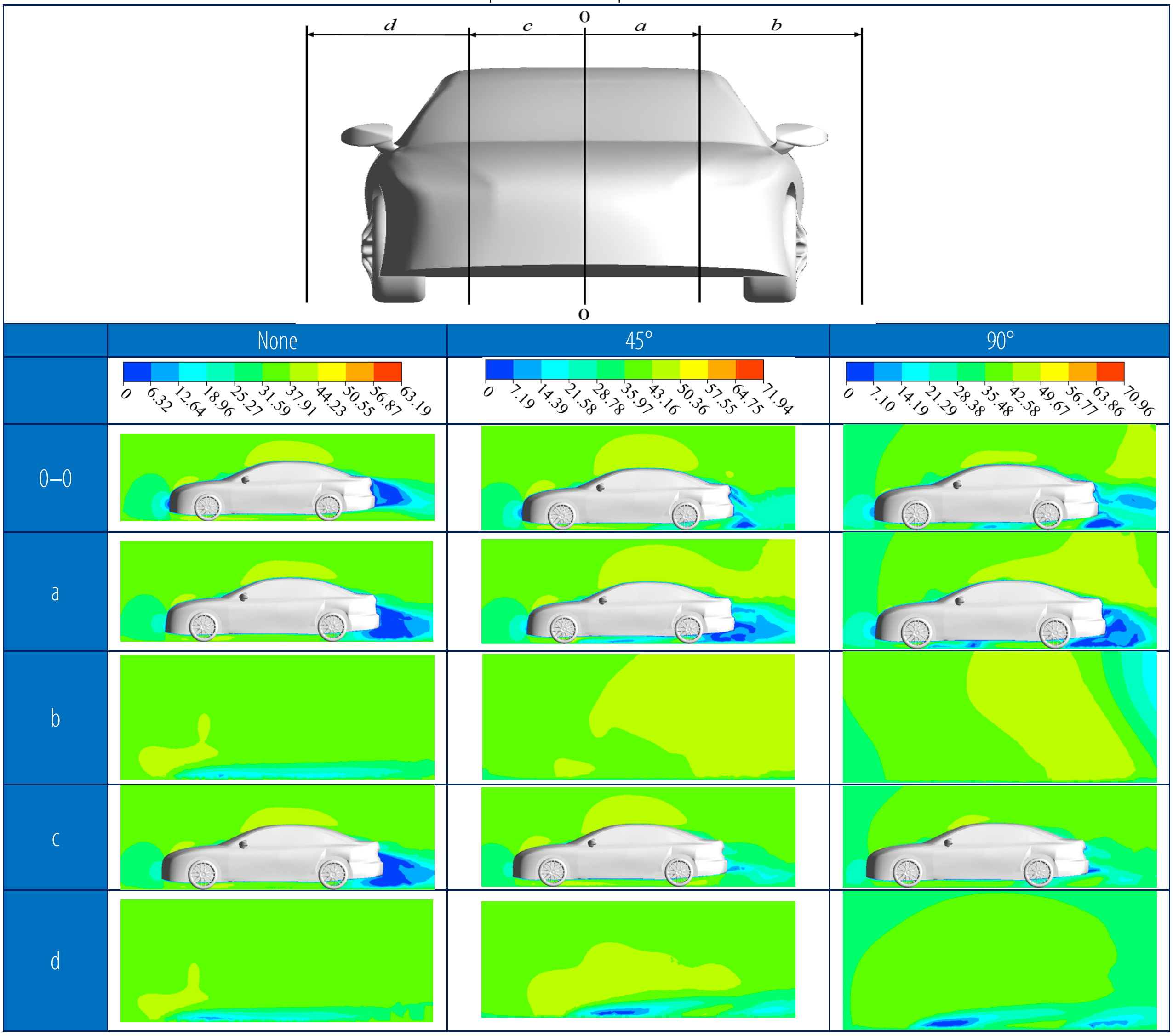
hits the air. Almost the same behaviour, pressure has and for the case when the acting angle of the wind is 45°. While when the acting angle of the wind is 90°, the maximal value of the pressure appears on the right side of the frontal surface of the vehicle. Also, is increasing the pressure on the side where wind acts on the vehicle.

Table 1. The air speed in different planes around the vehicle



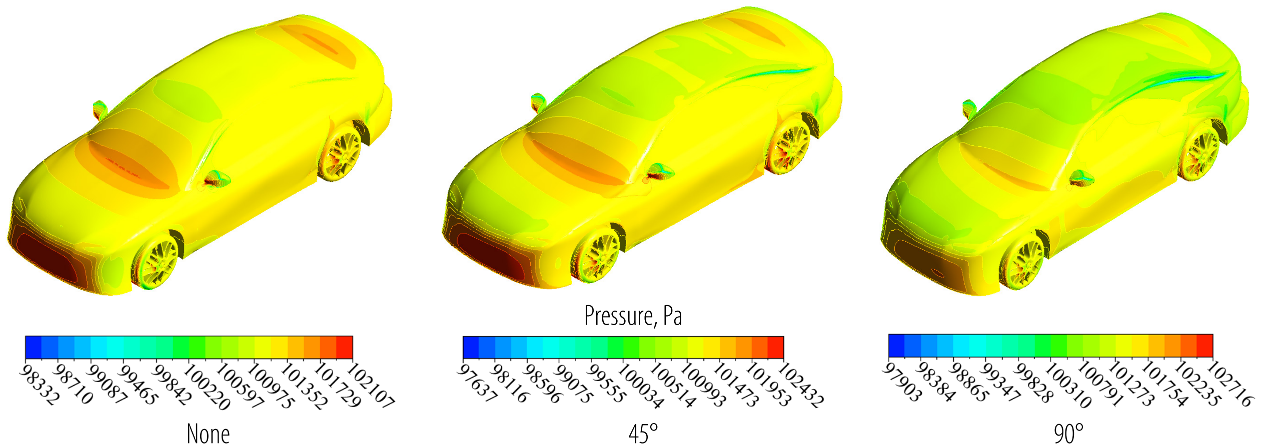




Figure 7. Pressure distribution on the vehicle surface

The lift coefficient is greater for the case with the crosswind, in respect to the case without crosswind, Figure 8. While with the increment of the acting angle of the crosswind, it rises and the lift coefficient for the front axle. This can cause the reduced steerability, or even worse the loss of contact between the front tyres and road, and the same finding was found when the air speed was observed. This is very inconvenient,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especially in the cases of accidental situations, because in the case of some sudden maneuverers can come to the vehicle stability disturbance.

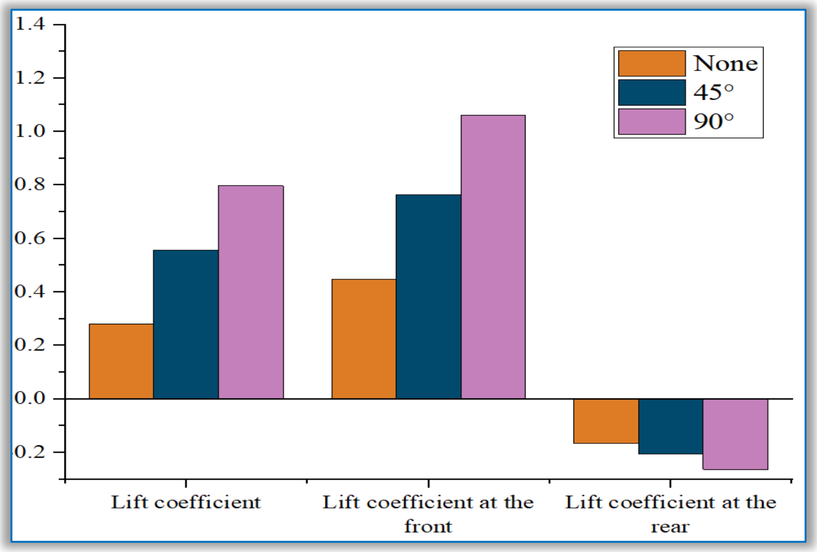


Figure 8. The vehicle lift coefficient, lift coefficient for the front axle and lift coefficient for the rear axle

Also, in the case, when emergency stopping is necessary, the brake force on the front axle will be decreased. The reduced contact between the front tyres and the road, as well as the value of the force of the crosswind (Figure 9), can cause loss of the vehicle control, in the case of some sudden manoeuvre.

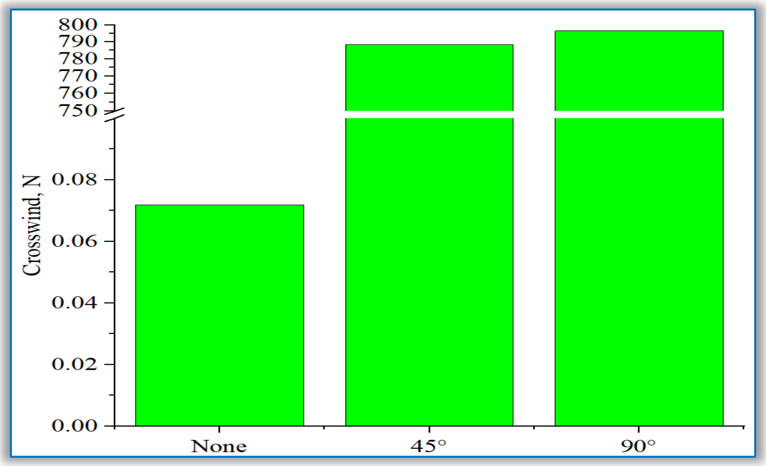


Figure 9. The crosswind force value

## 4. CONCLUSION

For safe vehicle driving, that is, for safe participation in the traffic, it is very important, not to come to the vehicle stability disturbance at any moment. By analysis of the influence of crosswind on the lift force value, can conclude that with the increment of the crosswind acting angle, rises the lift force, that is, rises the lift coefficient. The values of crosswind force, for crosswind acting angles 45° and 90°, are almost the same. So, in the conditions, when the crosswind acts on the vehicle, it is very important, not to do sudden maneuverers, because this will have a negative effect on the vehicle stability, as well as on the safety of the driver and other traffic participants. In future researches, should take into the consideration, the change of the vehicle speed, as well as the speed of the wind, and to investigate how will this affect on vehicle stability, all with the aim to determine the safety of all traffic participants, for the case, when the crosswind acts on the vehicle.

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