THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE XIV MECHANICAL ENGINEERING, ISSN 1224-5615
2002

THE DYNAMIC CONDUCT ANALYZE OF THE CAR BODY

As. Ing. Cătălin RĂDULESCU[1]
Conf. Ec. Dr. Ing. Adrian-Mihai GOANȚĂ[2]
Conf. Dr. Ing. Niculai HAUK[2]
[1]Universitatea "POLITEHNICA" din Bucureşti
[2]Universitatea "DUNĂREA DE JOS" GALAȚI

ABSTRACT

To project the actual car need to use more the computer. To reduce the time between the properly projection and the realization of the prototype it is necessary to realize more studies for the car body model, to reduce de number of trying

1. Introduction

To project the actual car need to use more the computer. To reduce the time between the properly projection and the realization of the prototype it is necessary to realize more studies for the car body model, to reduce de number of trying.

2. The aerodynamic conduct of the car body

The running process of the air that is involved when a car moving, has in general two forms:

- the running of the air through the external car;
- the running of the air through the internal of the car (interior car ventilation) and over building block of the car (during the cooling process).

The running of the air through the motor division depends on the running field round the car. The two fields need to be taken together.

The concentration of the interest it's for the resistance force witch is very important for car aerodynamics.

His adimentional coefficient, resistance coefficient of the air C_x has become almost synonym with aerodynamics form study. It can not be deny his important roll witch can be compare with that of the compression report for an engine with internal burning.

High performance, economy for combustible, air pollution emission and maxim speed are based attributes for a car. All this represent decisive arguments to commercialize an auto vehicle and all are influence by the rezistence force at the advance.

The study of aerodynamics conduct for an auto vehicle includes more components, out of this force.

The air running around the car it is responsible for his directional stability: his stability when it is moving straight line, aerodynamics stability in turn, the car answer at lateral wind. More, the external running of the air must to be modeled so that to eliminate the rain drops from the window and external mirror, to avoid to litter the headlight and the projectors, to reduce aerodynamics noise, to provide the cooling of the oil bath engine, for the cooling liquid radiator, for the brakes, etc.

The internal running must to provide, with the radiator help, the taking over and warm elimination that the engine it is losing, in the road conditions.

In the last, other internal running tide must to provide a comfortable climate in the interior car. In both cases - the cooling of the engine and the interior car ventilation – the two temperature fields are bound and need to be analyze together.

In conclusion, the aspects that are noticed by the aerodynamics studies have an important influence for the design of the car. His form must to provide all the aspects related anterior and not in the last aspect to respect some aesthetic principle.

The most important attributes for the running air round the car can be seen. For that we need to have a aerodynamics tunnel or a dummy, good for his dimensions, and smoke generator.

The resistance force for the advance it is proportional with square of the car speed. For a medium class car, at 100 km/h speed, the force has about 75-80% from the total resistance at the advance. To reduce that, involve a significant cut for the fuel consumption and pollution emissions.

The complete formula for the force is:

$$F_{p_X} = c_X \cdot A \cdot \frac{\rho}{2} \cdot V^2$$

where: F_{Px} = the resistance force at advance

C_x = the resistance coefficient for the air on the advance direction

A = the cross-entry maximum section aria of the car

ρ = density of the air

V =speed

To a given speed, the density of the air can not be influenced, so the force value F_{Px} can be cut reducing the cross-entry maximum section aria or the resistance coefficient for the air.

This coefficient depend by the form of the cross-entery section.

The dimension of the cross-entery it is determed by the utilization needs of the car, so the efforts to reduce the force F_{Px} will be focused to cut C_x with an efficient modelling of the external form.

The spaces dimension between the electrical lines gives indications for the force witch act on the vertical direction. The near field lines generate big running speeds and in consequence little static pressure conformable to Bernoulli equation:

$$P_t = P + \frac{\rho \cdot W^2}{2} = const.$$

where: P_t = total pressure

P = static pressure

$\frac{\rho \cdot W^2}{2}$ = dynamic pressure

w = the speed across the electrical line

Herefore, if P_t=const. and the term $\frac{\rho \cdot W^2}{2}$ have big values generated by the big running speed, the static pressure P has little value.

The pressure difference between the superior and inferior surface produce a resultant force witch act on a direction perpendicular on the moving direction, with down to up sense named lift. It tends to pick up the car from the roll road, so it is reducing the loading of the tire and the spot contact aria. All that represents a disadvantage for the direction stability of the car because, for a lateral given force, the sliding angle increase when the loading from the tire is less.

The front loading of the bridge is different from the back one and this difference generates a bad comportment when the car is turning.

The relative orientation of the car related to the road – the attack angle is modifying, increasing the pressure force, given by the advanced direction.

If the speed is less than 100km/h, the lift and the pitching moment have a low influence for the direction stability car, even if the wind is from lateral. To big speeds, this is not available, so the new research activities try to control it.

The little lift, in special for the back connector of the face traction car, is avowed goal for the design. To achieve this desideratum we can accept a little increase for the pressure force resultant from the moving direction. The face and back mask, applied, for the beginning, only for the competition car, never-failing in the last time from the automobile body serial line, have an important role to obtain a little lift force, a little resultant pressure force that is increasing the cooling air running volume.

The three effects can be different selected depending on the objectives.

The reducing effect for the advanced resistance force is based on the fact that the mask reducing the air speed on the inferior side car, attenuating the air flux contribution under the car to this force. This contribution is due, in special, to the unlinear nature, ridged surface under the car.

The lateral wind, the running of the air over the car became unsymmetrical, reported to the median longitudinal plane. The car should be in such a form that the force and additional moment to be little and the directional stability don't be affected.

In present the lateral wind problem isn't so important, caused by the increasing tendency of the car with motor and front traction and the weightiness center to this it is moving in front part.

Reducing F_{Px} when C_x is increasing it can be possible placing the null speed point down as much as possible. In consequence, in last years, the air intake radiator was placed more and more down.

To appreciate the aerodynamic action of the car body it is necessary to realize a detailed study. This study would be effectuated with the ADINA calculus program.

The program admits to visualize the running fields and the current line around the car body. Also it can be dignify the pressure of the epure witch characterized the respective form of the car body.

The section ADINA-F for the calculus program can realize the simulation of the air running on the car body in a aerodynamic tunnel.

To realize this aerodynamic study for the car body form supposes to follow a similar period form to realize the tri-dimensional model for the resistant structure of the car.

To realize the geometrical model need to model in two dimensions the profile form witch correspond to the median longitudinal plane of the car body.

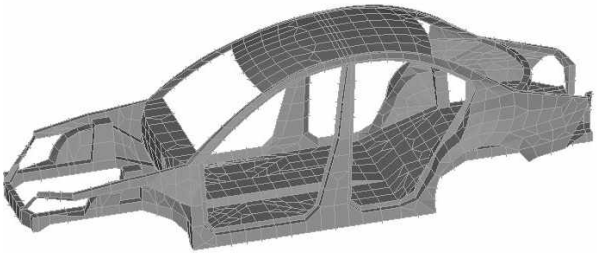


Figure 1: The model from the finite elements

The geometrical model is a plate with the aerodynamic tunnel dimension, from that was cut the anterior profile.
The aerodynamic tunnel dimensions were established depending on the high and the long of the total car, so to the superior side of the tunnel to exist the current lines uninfluenced by the profile form that is tried.
The total high of the tunnel was fixed to 4 m and the length of the tunnel 9 m.
Having this dimensions and the point that the surface need to be without acute peaks, was building the plate witch represent the geometrical model, having "cut" the tried model.

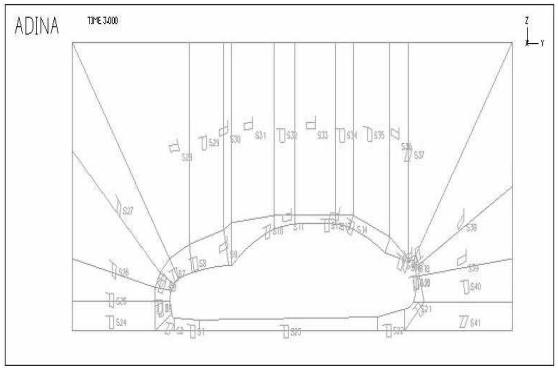


Figure 2: Geometrical model

To define the geometrical model suppose to establish the material type, in fact of the fluid witch is running over the profile. This is from the type K-omega, defined in the ADINA program, for that was introduced kinetics body of oil $\eta=1,7894*10^{-5}$ Ns/m^2 and the fluid density with $\rho=1,2250$ kg/m^3. The fluid is the modeled air for the turbulence running establish to the section "flow assumptions". Here was established the running type being bi-dimensional (2 d fluid).
To establish the margin conditions suppose to annul all the liberty degree from the line that defined the profile submits to the loading and also on the lines witch simulates the being of the aerodynamic tunnel walls.

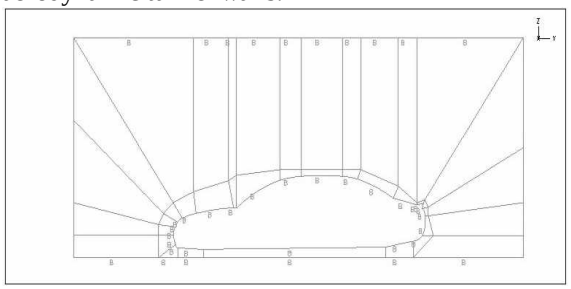
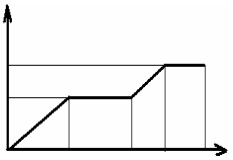


Figure 3: The margin conditions

To applied the loading suppose to define the loading like type speed on the lines witch simulated the access in the tunnel section.
In this case the variation is along by the period of three second, like:


The calculus program will calculate the speed and the pressure in 64 moments, witch represent the calculus steps. For a good appraisal of the results it is necessary to be introduced a big number of steps.

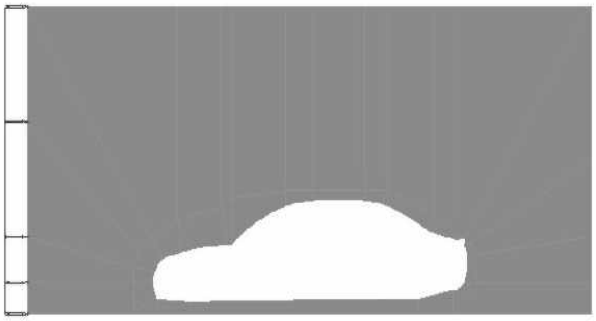


Figure 4: The loading application

In this goal it is establish the discredit density, witch have a huge importance when you are trying to obtain real results.
Like in tri-dimensional geometrical case, the discredit density is limited by the used computer resources.
After you have established the discredit density you need to realize the properly discredit for the defined surfaces.

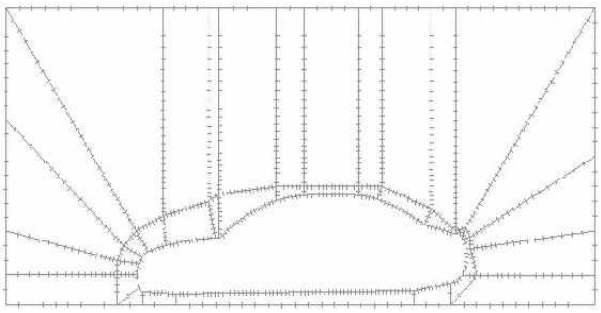


Figure 5: Establish the discredit density

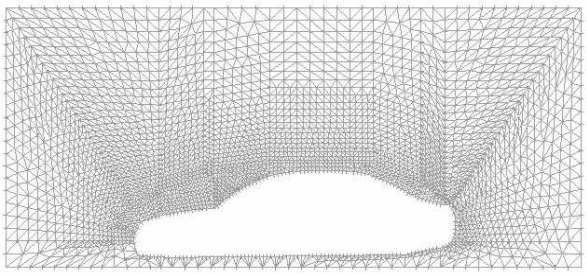


Figure 6: The model with finite elements

The aerodynamic action study of the car body follow to put in evidence the pressure fields and the

running speed dimension of the air in the air layer adjacent to the form, or bellow by that
Also, the ADINA calculus program permits to visualize the running form along by the model profile putting in evidence the speed vectors.
This three aspects characterize in a adequately measure the action of the profile when the automobile organs are cooling, habitacle ventilation, not to contaminate the vitrate surface and the optic blocks, the possibility to reduce the resistance coefficient of the air putting in evidence and reducing as much as possible the vortex moving. All this aspects will be presented in the next rows for three form variants of the automobile profile trying to determinate the influence of the different constructive modifications on the aerodynamic action.

Model I

The first model tried represent the car body form that was the base for this analysis.

1. The pressure field

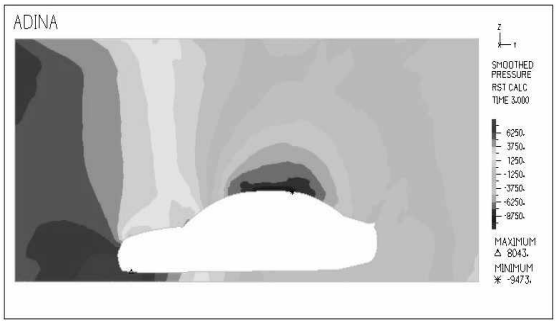


Figure 7: The pressure field for model I

Conformable to figure 7 it can be observed the disposition of the pressure points, respective on maximum depression. The maximum pressure appears in the front mask area as well as the radiator grid, with favorable implications related to the cooling efficient of the motor during the moving. The maximum depression area is disposed to the posterior part of the ceiling.

Other favorable aspect, of the pressure distribution from the 7 figure, is that the pressure increase in the wind screen based zone, where are arrangement the fresh air drawing connections witch is necessary for the habitacle ventilation.

The aileron, set on the luggage rack hood, did not generate a depression area, his effect being negligible.

2. The running speeds

Figure 8 evidences the running speed values of the air along of the car profile at the maximum speed.
The favorable aspects of the speed distribution obtained are:

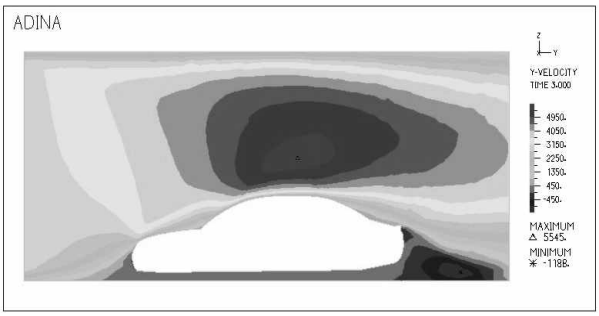


Figure 8: The running speed values of the air for model I

1. Uncontaminated vitrate surfaces and optic block during the moving.
2. The running air with little speed under the car has good influence to reduce C_x component, due to the irregularity constructive of the surfaces.

The maximum speed area is situated over the ceiling witch is generated by the running section contraction.
The minimum and negative speeds area, witch announce the vortex forming, is situated in the back side of the profile, near the ground. This area is a little bigger because of the aileron present.

3. The running form (the speed vectors distribution)

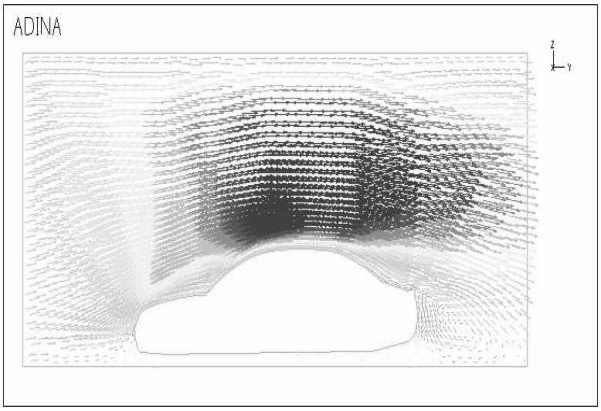


Figure 9: The speed vectors distribution for model I

Figure 8 shows the air running form and the running speed values witch correspond with that from the figure 9. It is good to remark that in the minimum and negative speed area is formed vortex zone with horizontal ax, perpendicular on the moving speed. It can be observed that this turbulent zone has little dimensions.
The running air for other sections it is possible without the vortex appearance, witch point out a good aerodynamic forming of the car.

Model II

In the second geometrical model construction it has renounced to this accessory because the pressure field and air running form have shown a reduced influence of the aileron.

1. The pressures field

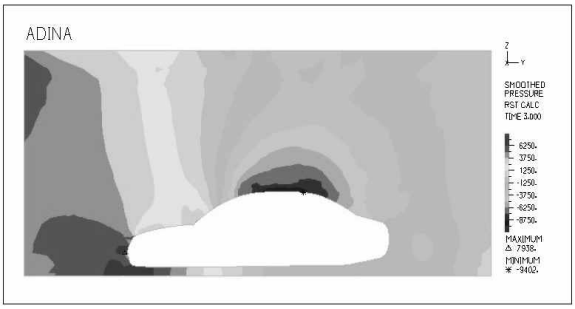


Figure 10: The pressures field for the second model

The aileron renunciation has modified the maximum pressure point position from the front air connection level of the spoiler with positive effects for the cooling motor. Also, it was obtained an increase for the pressure in the back side of the profile. The maximum depression area disposing is the same like in model I.

2. The running speed

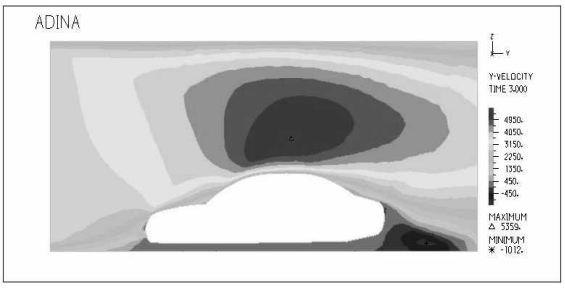


Figure 11: The running air speed values for model II

The changes that have been brought for the running speeds, when they have renounce to the aileron, include the increase of the values for the lighthouse and wind screen area. At the same time, it have obtained the decrease of the little or negative speeds aria from the back of the car and going down near the sol.

3. The running form

Related to the air running form it was obtained significant good changes for model II, trying to reduce the turbulent zone.

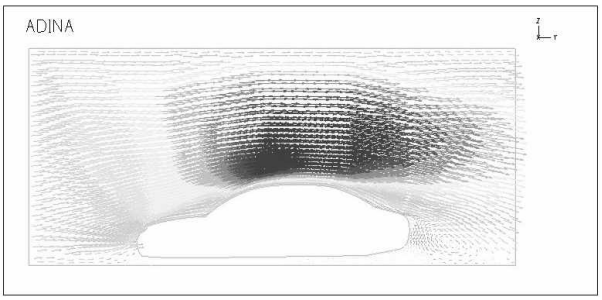


Figure 12: The speed vectors distribution for model II

Model III

Model III was build to increase the volume of the luggage rack. So the hood was over increased and redrawn the profile over the back spoiler.

1. The pressure field

The disposition of the maximum pressure zone is the same with the one for model II. The difference appear to the maximum depression zone witch was increase. Also, it can be observed a pressure reduction for the back side of the car. The positive aspects of the cooling motor, unpollution vitrat surfaces and beacons are maintained.

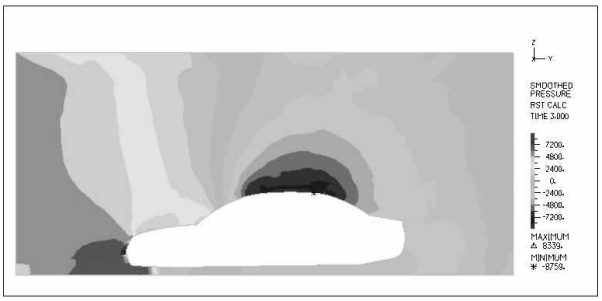


Figure 13: The pressure field for model III

2. The running speeds

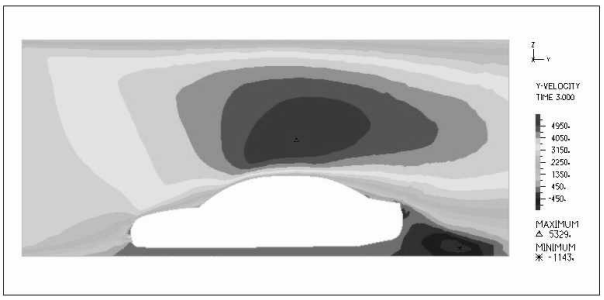


Figure 14: The running air speed values for model III

In the case of the running speed values that was calculated for model III it can observed that the positive aspects stated at the anterior model are the same, but produced an increase of the zone with a high probability that forms vortex. This situation must to be avoided.

3. The running form

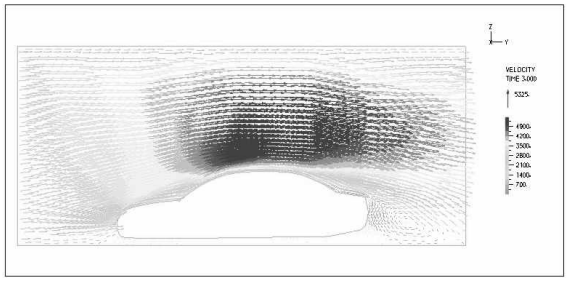


Figure 15: The speed vectors distribution for model III

In this case, the air running form from the figure 15 point out the significant increase of the vortex zone, situation that is undesirable from the additional expenditure of energy point of view.

3. Conclusions

To establish the general form of the car body imply to realize a compromise between: to assure a good comfort conditions, a big transport capacity, aerodynamic stile and not in the last point a nice aspect. The studies on the computer for the car model help us to reduce the car realization time.

4. References

[1] **Răţoi-Ionescu Alexandru; Rădulescu Cătălin** - *Modelarea structurii caroseriei unui autovehicul* – Conferinţă Naţională Cu Participare Internaţională "Cercetarea Ştiinţifică În Condiţiile Integrării Europene" Brăila 28-29 Mai 2004 - Editura AGIR Bucureşti, 2004;

[2] **Rădulescu Cătălin; Răţoi-Ionescu Alexandru** - *Studiul comportării la impact a unei caroserii de autovehicul* - Conferinţă Naţională Cu Participare Internaţională "Cercetarea Ştiinţifică În Condiţiile Integrării Europene" Brăila 28-29 Mai 2004 - Editura AGIR, Bucureşti, 2004;

[3] **Untaru Marin; Stoicescu Aurel ş.a.** – *Dinamica autovehiculelor pe roţi* – Editura Didactică şi Pedagogică Bucureşti, 1981.