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[1.]Dániel MOLNÁR, [2.]Gergely DEZSŐ

# A CASE STUDY ON PRESSURE AND VELOCITY FIELD IN THE BACK HALFSPACE AROUND AND AFTER A CONTAINER LORRY

[1-2.] University of Nyíregyháza, Institute of Engineering and Agricultural Sciences, Department of Physics and Production Engineering, Nyíregyháza, Sóstói út 31/B, H-4400, HUNGARY

**Abstract**: Experimental and theoretical airflow analysis of vehicles is a vivid field of research because beyond decreasing aerodynamical losses opportunities for energy recovering also get into the focus of investigations. A more and more important requirement to vehicles is the power efficiency and its important substance, the energy recovery. A substantial part of energy gained from the fuel in internal combustion engines transferred into the kinetic energy of air, which later dissipates into the environment. Recovering energy from the moving air around the vehicle seems to be a promising idea, but raises several questions. One of the main points is to find appropriate places from where it is possible to retrieve energy without deteriorating aerodynamic features of the vehicle. This is that's why as a first step we simulated the airflow behind a combination vehicle. Velocity and pressure fields are also presented.
**Keywords**: sensitivity test, finite element method, velocity distribution, pressure field, airflow simulatio

## 1. INTRODUCTION

Energy efficiency of vehicles can be improved by several methods [1]. Such for example streamlined shape, the improving the efficiency of the internal combustion engine, the drive chain, and the use of various energy recovery equipment. Nowadays the theoretical background of flow dynamic simulation is also an intensively researched area [2].

In this paper, we report a calculation that examines the possibilities of an energy recovery system. The system retrieves the moving energy of the flowing air. This requires the knowledge of the airflow around the vehicle. We have chosen a common vehicle type for the subject of the test: one of the possible variants of a road vehicle combination. In a previous study, the whole vehicle combination was modelled [3]. For more detailed studies, we narrowed the examined area. This study presents the sensitivity analysis and the flow characteristics obtained by solving the accepted model.

## 2. MODEL

The front of the truck was removed to save significant amount of computing capacity and time. The model thus obtained is shown in Figure 1. The flow of the tractor that is broken by the tractor towards the end of the trailer is lighter, so we have not changed the boundary conditions, a wind speed of 80 km/h is uniformly distributed.

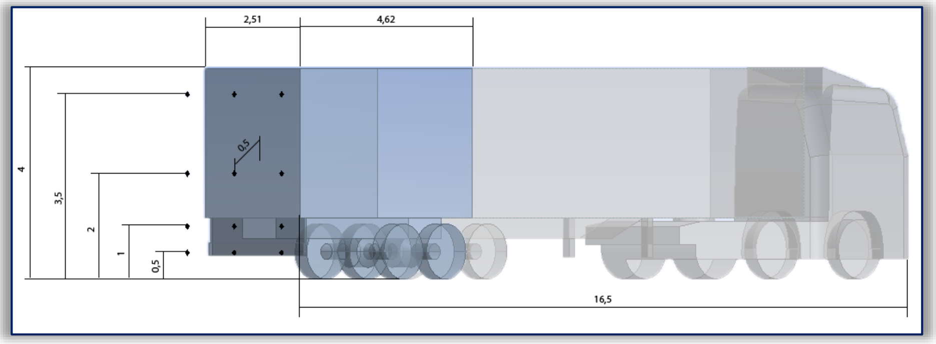


Figure 1. Rear part of the vehicle was studied, black dots were selected as control points for sensitivity analysis

## 3. SENSITIVITY ANALYSIS

During the sensitivity test we started from a basic finite element mesh, and then we continually reduced the size of the elements, always bisecting them. During the calculations, we recorded 12 control points. These control points were located half meters behind the trailer, 1, 2 and 3,5 meters above ground, in the median plane of the vehicle and in the two outermost planes (Figure 1). In each control points pressure, absolute speed, and velocity per component were recorded, and we calculated the relative changes as a percentage of values calculated with previous mesh. This was repeated until the relative changes fell below a certain value.

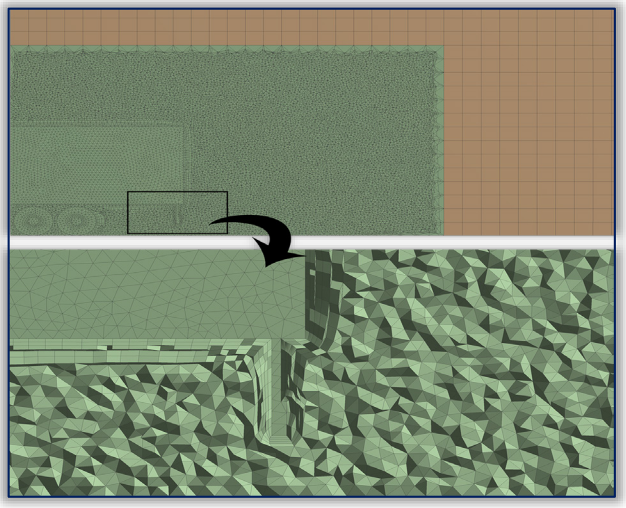

Figure 2. Finite elements close to the body of the vehicle. Inflation elements were applied along the solid surface

Pressure was considered as control quantity. It means that mesh was accepted when the last relative change in pressure was less than 0.5 %. The maximum relative change between the C and D projects in terms of pressure is 0,008044188 percent, which proves that the pressure calculation results are no longer sensitive to the refinement of division.

It must be noted that relative changes in velocity absolute value and velocity components did not decrease below 1%. This means that further refinement would be necessary in case velocity was selected as control quantity.

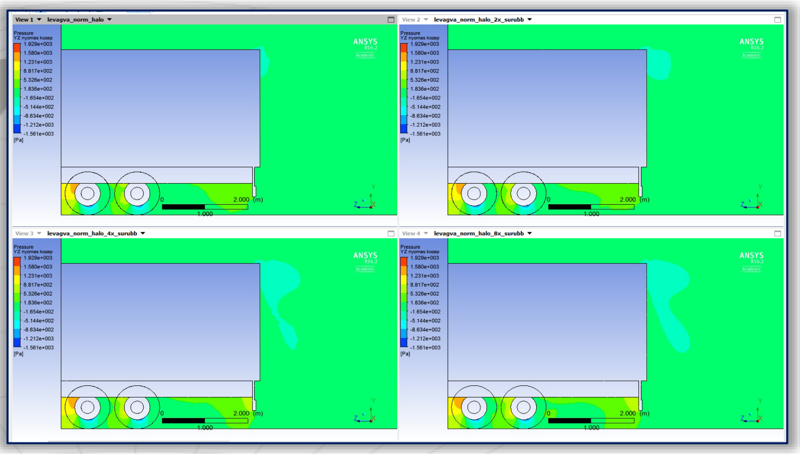

Figure 3. A colormap plot of pressure distribution on the symmetry plane of the vehicle calculated with different finite element meshes (the finest is at right bottom)

In sensitivity analysis, calculation with different mesh size was denoted with letters A, B, C and D. On Figures 3-7 we demonstrate spatial distribution of some illustrative quantities resulted from calculations with all four different mesh size. On each figure subpictures belong to A, B, C and D simulations form left to right and from up to down. Colour codes applied on subfigures on a certain figure are the same, making the comparison easier.

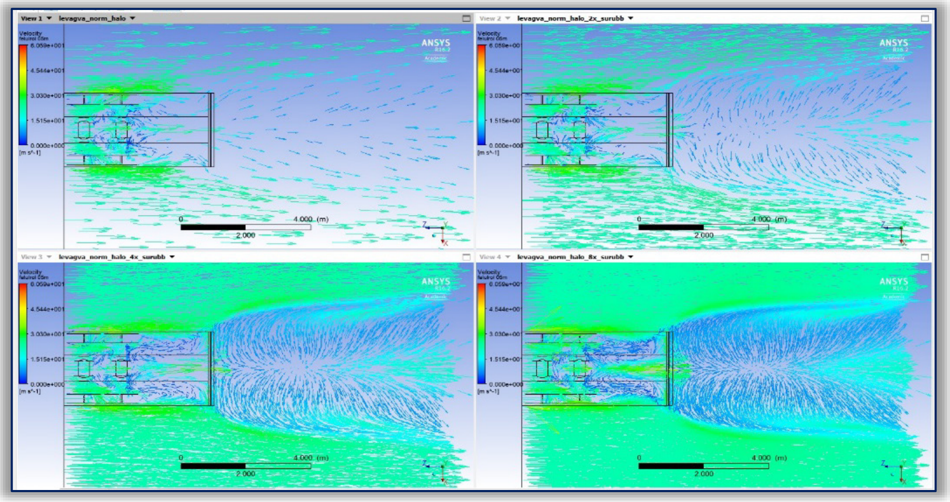

Figure 4. Vector plot of airflow on a horizontal plane at 0.5 m distance below the upper part of the vehicle calculated with different finite element meshes (the finest is at right bottom)

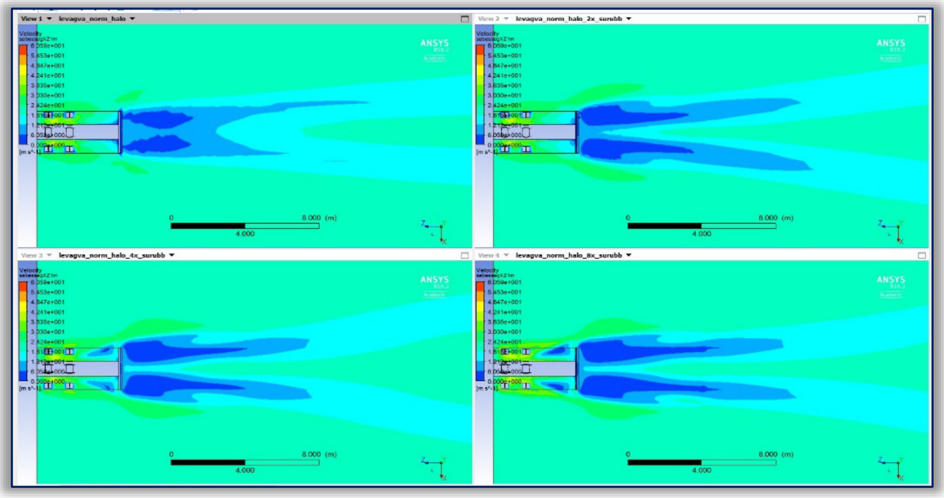

Figure 5. Color map of velocity absolute value on a horizontal plane at 1 m distance below the upper part of the vehicle calculated with different finite element meshes (the finest is at right bottom)

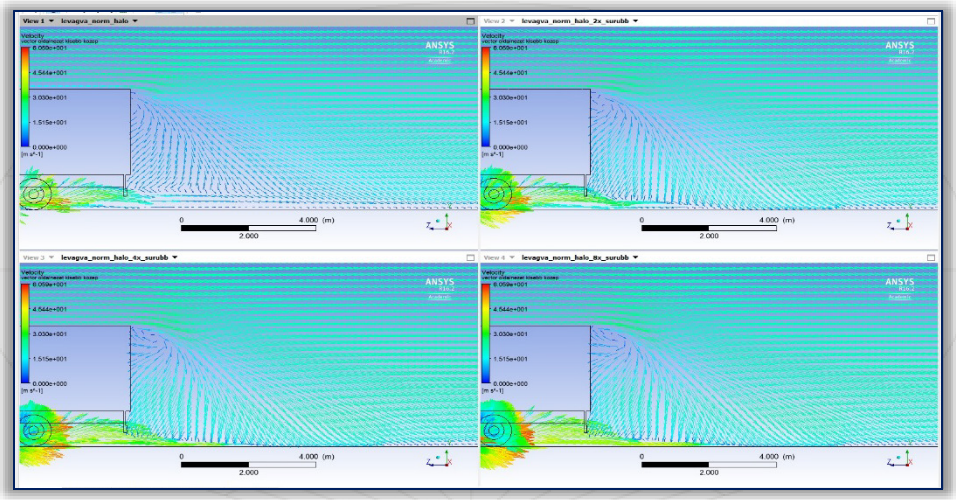

Figure 6. Vector plot of airflow on the symmetry plane of the vehicle calculated with different finite element meshes (the finest is at right bottom)

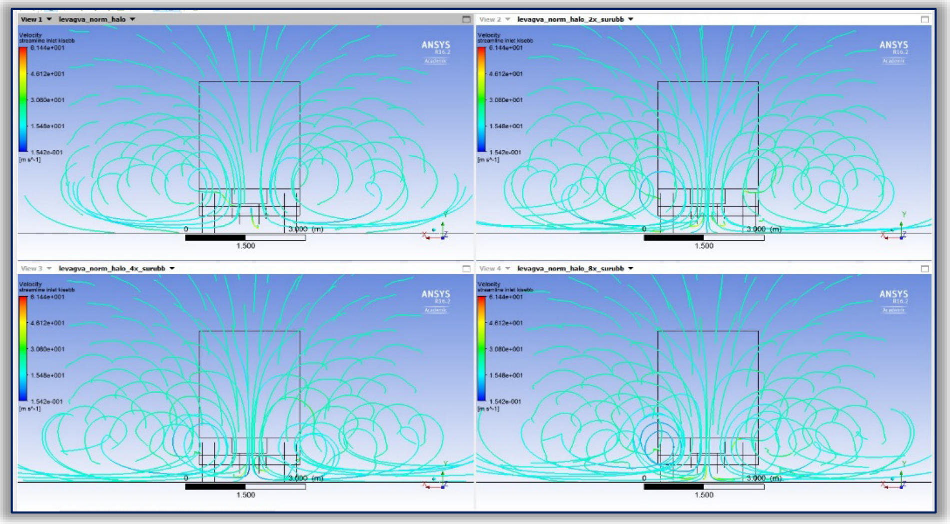

Figure 7. Streamline plot of airflow from the back view, calculated with different finite element meshes (the finest is at right bottom)

Figures 3-7 demonstrate well that simulation results for distribution in space of important quantities of the flow like pressure and velocity is substantially biased by mesh size. Figure 3 shows for instance that a characteristic low-pressure area behind the upper part of the rear wall of the trailer is well visible with the finest mesh (D), but is not visible almost at all with the initial mesh (A).

## 4. RESULTS

Figures demonstrating sensitivity test show results of the simulations with eventually accepted, finest finite element mesh in their right bottom part. So from this point we talk about and the reader should focus on the right-bottom part of Figures 3-7.

The finite element distribution created with the smallest element size can be seen in Figure 2. It can be seen, that there is a dense mesh in the immediate vicinity of the vehicle, this section is subject to a sensitivity test, but enough space is required to prepare the simulation, with constant hexahedral elements [3]. The number of elements was about 7 million. Figure 3 show that a low-pressure area is formed behind the top side of the rear wall of the trailer. This can be related with eddy visible on velocity plot Figure 6.

Figure 4 demonstrates vector plot of velocity at a horizontal plane above the roan in 0.5 m distance. Results of simulation with the finest mesh show that on one hand a highly complex flow is present under the rear end of the vehicle, on the other hand a very characteristic, long, double-eddy flow is present behind the vehicle, which may be comparable or longer than the whole vehicle in length. In this eddy tube the main air stream is thwart, i.e. moves almost along the x-y plane.

Figure 5 shows the same pattern in the language of pressure in 1 m distance from the road. Figure 6 is a vector plot of velocity in the vertical middle plane of the model. Most interesting area of this plot is the lengthwise eddy (moving mainly in plane z-y). Streamline plot on Figure 7 demonstrates airflow behind the vehicle from rear point of view.

## SUMMARY

One of the special parts of the vehicle type we have chosen from a flow-related perspective has been studied by flow simulation. During this publication, we conducted a sensitivity analysis of the finite element distribution.

Four different finite element meshes were applied in the sensitivity test, the fourth, finest division was accepted based on a slight change in pressure values. The calculated pressure and velocity distribution as well as the flow image show a good qualitative match with the experienced airflow of moving vehicles.

Both at the top and bottom part of the rear end of the trailer areas can be found wich may be worthy for further investigation from the viewpoint of energy recovery.

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