DESIGN OF AN AERODYNAMIC AID FOR THE UNDERBODY OF A TRAILER WITHIN A TRACTOR-TRAILER COMBINATION

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Abstract: The significant increase of road transport combined with the increasing environmental issues and fuel prices has renewed the interest in truck design. Reducing the aerodynamic drag has a large positive influence on the fuel economy, and the belch of harmful exhaust gasses.
Extensive experimental design of aerodynamic concepts in the wind tunnel resulted in several solutions which fit within the today’s European regulations. A straight side skirt with a leading edge profile reduces the drag up to 14% which results in a reduction of fuel consumption of 7%.
1 INTRODUCTION

Background. Cargo transport by road using trucks is still one of the most efficient transport solutions within the European context. This fact manifests itself in an increasing amount of trucks on the road and the associated increased total volume of fuel consumed. The rising fuel prices force the transport companies to cut cost in order to stay competitive in this aggressive, fast changing and growing market. The expected significant road transport demand in the next twenty years and the increasing environmental constraints has renewed the interest in truck design; any reduction in truck fuel consumption can be associated with large annual fuel cost and considerable emission savings. Generally there are two ways to reduce the fuel consumption of a vehicle. One can improve the efficiency of the power delivered by the engine, the available power, or one can lower the required power to overcome the different forces acting on a truck traveling over the road. The latter can be achieved by reducing the weight of the vehicle, reducing its aerodynamic drag and by reducing the friction resistance of the tires. When driving at highway speeds of 85km/h, more than 40% of the trucks fuel consumption is caused by aerodynamic drag, [16].

Past research. The reduction of fuel consumption of trucks by aerodynamic means has become an accepted practice in the last decades by installing a combination of add-on devices for the tractor and the trailer, while keeping its original boxed shape. Also modifications of the general shape of the vehicle improved the aerodynamic efficiency in a positive way. In the past several aerodynamic devices were developed for the front and top of the tractor, the back of the trailer and for the gap between the tractor and trailer, [9, 18, 19]. Also several aerodynamic aids for the underside of the trailer were investigated and tested in the wind tunnel. The solution of Ortega [12] for a trailer underbody included some kind of side skirt but then placed as a long wedge. They achieved a maximum drag reduction of 6.25% in the situation of zero yaw angle. The investigation team of Wood and Bouwer [19] developed a high momentum mud flap which achieved a drag reduction of more than 10%. Storms [15] and his assistants executed several wind tunnel tests with a generic tractor-trailer model in a pressurized wind tunnel at a scale of 1/8, among which solutions for the undertray of the trailer. They tested several types of side skirts and obtained drag reductions between 6.2% and 11.8%.

Present research. Within a research program of the Delft University of Technology the last years, several aerodynamic add-ons for the underside of a trailer were designed and tested in the wind tunnel. The chosen region of the vehicle to improve the aerodynamic behavior of the flow was the underside of the trailer. This choice is supported by the fact that the underbody flow of trailers is characterized by highly turbulent and separated flows [17]. About 30% of the total drag of tractor-trailer combination originates from the underside of the vehicle, [17]. The underside of the trailer there allows enough space to incorporate an aerodynamic add-on within the European regulations [21]. With the aid of a scaled model an aerodynamic add-on for the underside of the trailers is developed by iterative design processes in the wind tunnel. Besides drag measurements, the pressure coefficients are determined at the back of the vehicle to give an indication of the influence of drag decrease and the pressure at the back surface. The design together with the mutual drag reduction differences of several aerodynamic devices for the underbody of a trailer in a tractor-trailer combination is presented in this paper.
2 EXPERIMENTAL SET-UP

2.1 Aerodynamic add-ons

Two different types of add-ons are being designed in this work: side skirts and a full underbody. Both types will be discussed briefly below.

**Side skirts.** Side skirts are well known structural, aesthetic and aerodynamic aids in the bodywork and transport sector. Skirts are vertical plates which are mounted in the longitudinal direction of the vehicle. The main idea of the side skirts is preventing the flow to go under the trailer with all its disturbances like support legs, storage boxes, suspension, axles and wheels, see fig. 2. Transport companies are obliged to install side bars due to safety reasons to have a sideways protecting construction (guide line 89/297/EEG, [21]) which prevents cyclists and pedestrians to end up under the trailer. All the side skirts applied during the wind tunnel tests were designed according to this European guideline.

**Underbody.** The underbody for the trailer was inspired by the underbodies of personal and race cars. The purpose of the underbody for the trailer is to guide the flow around the obstacles like the support legs, the pallet box, the axles and the wheels (see fig. 1) in order to decrease the disturbances and thus the aerodynamic drag. The front part of the underbody catches the flow coming from the front of the tractor and guides it along the support legs over the pallet box. Behind this a channel is formed which directs the flow over the axles and between the wheels. The rear part can be seen as a diffuser which expands the flow into the wake of the trailer. The dimensions of the different parts of the underbody are defined by the geometrical shape of the model. A diffuser angle of $10^\circ$ is chosen based on the work of Ruhrmann and Zang [20].

2.2 Wind tunnel model

A $1/14^{th}$ scaled truck model (TAMIYA Mercedes Benz 1838LS truck and TAMIYA Container-Trailer) was used to execute the experiments. The width, height and width of the truck model is respectively 205mm, 298mm and 1100mm, fig. 2. The model is adapted in order to generate a turbulent attached boundary layer directly to the back-end of the trailer. The initial truck model had sharp corners which would result in flow separation at the front edges and is not a realistic representation. Any aerodynamic improvement at the bottom and back of the trailer would be ineffective. A new cover, fig. 2, with properly chosen round-off edges [10] has been made that prevent flow separation at the front cabin corners and initiates a turbulent boundary layer before it reaches the back edges of the tractor [4]. The model was not equipped with a cooling and fans system and is mounted with several supporting points together with a support plate belly-up due to the location of the balance system, fig. 1 and fig. 3.
The Reynolds number for a full scale truck, based on the square root of the frontal area of 
\[ A = 10.34m^2 \], air density \( \rho = 1.225kg/m^3 \), air viscosity \( \mu = 1.7894 \times 10^{-5} \) and a driving velocity of 25m/s, becomes \( 5.5 \times 10^6 \) [4]. The operating velocity during the experiments was 60m/s and the scaled wind tunnel model had a frontal area of 0.057\( m^2 \). This gives a Reynolds number of \( 0.80 \times 10^6 \) which is high enough to test bluff bodies in proper manner in the wind tunnel, [14]. After measuring the drag coefficient in a velocity range of 50m/s-120m/s, no Reynolds effects were deducted: the drag coefficient stayed constant over the Reynolds number range. No wind tunnel corrections methods were applied on the dynamic pressure, because one is only interested in the \( \Delta C_D \) of the several configurations.

2.3 Wind tunnel configuration

The wind tunnel experiments were deducted in the Low Turbulence Tunnel (LTT, fig.4) of the faculty Aerospace Engineering at the Delft University of Technology, The Netherlands. This closed circuit wind tunnel has an octagonal test section with a cross sectional area of 2.07\( m^2 \) (width of 1.8m; height of 1.25m, fig.5) and with parallel wind tunnel walls. The maximum operating velocity of the wind tunnel is 120m/s; the turbulence intensity can be changed in the range 0.02-0.1%. The empty wind tunnel test section is calibrated for the wind velocity with the aid of a pitot tube by measuring the dynamic pressure and compare it with a static pressure difference between two locations in front of the test section.

Figure 2: Wind tunnel model dimensions
Figure 3: Experimental set-up with ground board in LTT
Figure 4: Low Turbulence Tunnel
Figure 5: Cross section of LTT with ground board
Buckley [2] concluded after testing aerodynamic devices on the road and in the wind tunnel that the non-simulation of wind turbulence in the wind tunnel tests appears to be a significant contributing factor to the source of disagreement between the wind tunnel and over the road drag reductions. Although the turbulence intensity of the flow has influences on its behavior there is decided to perform the tests with the maximum turbulence intensity of the LTT, which is 0.1%, and no further effort was put into artificially increasing the turbulence intensity.

2.4 Ground effect

Due to the presence of a road vehicle a boundary layer is developing on the road itself. This boundary layer and thus the presence of a ground floor influences the boundary layer of the lower surface of the vehicle and its drag behavior. The wind tunnel used is not equipped with a moving belt which is desirable to investigate the ground effect of, for instance, race cars. Ground simulations and its study have been the subject of many research projects [1, 3, 7, 8, 11]. The most basic simulation approach used for passenger cars is the most direct and simple one: to test a vehicle on a fixed surface. The major issue is a too thick approaching floor boundary layer. According to Cooper [4, 5] one can conclude that a fixed-floor with a thinned boundary layer is sufficient for current automotive and commercial vehicle applications, particularly where the underbody clearances are large and the underbodies are rough which is the case with tractor-trailer combinations.

To test the vehicle the model is suspended on a parallel floor which has an offset of 300mm with respect to the upper (horizontal) wind tunnel wall and has the same width as the test section, fig.3 and fig.5. On the rounded front edge of this ground plate develops a new thinner boundary layer in comparison with the thick boundary layer on the wind tunnel wall. This solution together with the conclusion of Cooper [4] and the fact that one was interested in the drag coefficient differences between the several aerodynamic aids and not in absolute values, will satisfy for these experiments.

2.5 Measuring techniques

The six-component mechanical balance system measures the resulting aerodynamic forces acting on the truck model. Here only the drag coefficient $C_T$ of the vehicle will be discussed. The direction of $C_T$ is orientated in the longitudinal direction of the vehicle. The drag coefficient was averaged by 20 measuring points.

The pressure at the back surface of the trailer is measured to calculate a corresponding pressure coefficient $C_{p,\text{back}}$ in order to investigate its relation to the change in drag coefficient $C_T$ and its response towards different aerodynamic add-ons. The pressure measurements were executed with the aid of Esterline Pressure Scanners [22] which can measure 30 different pressure orifices, nicely divided over the back surface in a raster. The diameter of each pressure tab is 0.4mm and had a length of 15mm. The pressure taps were connected with the pressure scanner by flexible PVC tubes with an internal diameter of 1mm. The pressure scanner itself is placed in the back of the trailer. Each pressure measurement is an average of 15 000 pressures. This measuring process takes approximately 1.5 seconds meaning each pressure tap is measured 500 times. From Duel and George [6] it turned out that the fluctuation of the near wake is about 15Hz: the averaged pressure field is captured.
3 EXPERIMENTAL RESULTS

During the campaign more than 100 different aerodynamic devices were built and tested on different vehicle configurations. Only a small selection of the many solutions is being discussed below. All the drag coefficients $C_T$ of the different aerodynamic devices will be compared with the standard tractor-trailer combination with rounded trailer corners, see fig.7(b). This standard trailer has an uncorrected $C_T$ of 0.443 (zero yaw angle) and will act as the reference drag coefficient, fig.6. A comparison of the drag coefficient results in a $\Delta C_T$ which is regarded as percentage of the reference truck and calculated with eq.1.

$$\Delta C_T = \frac{C_{T,\text{mod}} - C_{T,\text{ref}}}{C_{T,\text{ref}}} \cdot 100$$  \hspace{1cm} (1)

The results which correspond with yaw angles of 12.5° or higher are unreliable because the wake of the model touches the tunnel wall and influences the measurements. This wake interference with the tunnel wall was clearly noticeable due to the change in noise level coming from the wind tunnel.

3.1 Trailer

The rounded trailer, the frontal surface of the trailer is rounded as can be seen in fig.7(b), is the reference configuration to which all the other trailers will be compared. The clean configuration, fig.7(a), is not equipped with rounded trailer corners. This resulted immediately in a drag increase with respect to the rounded trailer, especially with increasing yaw angles as noticed in fig.6. Removing the mud flaps, fig.7(d), gives a general drag decrease of 5% ($\Delta C_T = -0.022$), fig.6. Blocking the underbody flow, fig.7(c), by mounting a vertical plate at the back between the underside of the trailer and the floor has disastrous effects on the total drag, fig.6: a $C_T$ increase of 0.102. This indicates that the underbody flow is crucial for the drag built up of a truck. All the trailer configurations being discussed below have a trailer with rounded trailer edges at the front surface and is equipped with mud flaps.
3.2 Add-on: side skirt

The most basic straight side skirt with covered wheels, fig. 9(a), reduces the drag coefficient $C_T$ with 11% ($\Delta C_T = -0.049$) at a yaw angle of zero degrees and stays almost the same with increasing yaw angle, fig. 8. Existing side skirts often have the front and rear edge cut off for aesthetic purposes and aerodynamic reasons. The results show that a steep cut back-edge, fig. 8, reduces the drag coefficient even further. If the front edge of the straight side skirt also has a cut off corner, fig. 9(c), a 12% drag reduction is obtained that rises smoothly until 13% at $10^\circ$, see fig. 8. The above different configurations for the straight side skirt have covered wheels, while real trucks often have open wheels. The existing side skirts with uncovered wheels, see fig. 9(d), perform aerodynamically much worse. Fig. 8 tells us that uncoverd wheels introduce a lot of turbulence which results in lesser drag reduction: about 4% at zero yaw angle, or an increase of $C_T$ with 0.018.

A first modification on this type of aerodynamic aid is the round side skirt, fig. 11(a), which encapsulates the pallet box in a round curve and covering the wheels towards the back of the trailer. The reduction in aerodynamic drag is 12.5% or $\Delta C_T = -0.055$ at a yaw angle of zero degrees and has its maximum at of 14.5% ($\Delta C_T = -0.064$) at $6^\circ$ as plotted in fig. 10. If the bottom of round front side skirt and the back end is closed, as shown in fig. 11(b), the drag measurements show that the drag reduction was less then the solution with the open bottom, fig. 10.

The side skirt with the sharp front, fig. 11(c), is an alternative for the round front side skirt and can be produced more easily. In stead of a curved surface, the two side-skirts are coming together in a point just before the pallet box. The side-skirt with the sharp front has almost the same results, fig. 10, than the round front side skirt. The difference between these two at zero yaw angle is small, even with increasing yaw angles.

The last side skirt discussed in fig. 10 is the solution with the hollow front, fig. 11(d), instead of the more spherical round front side skirt. This hollow front lies parallel with the turning radius of the tractor. At yaw angle of zero degree the hollow side skirt induces the biggest benefit in drag coefficient, fig. 10, but is not that efficient as the round front side skirt when the yaw angle increases.
The straight side skirt with the vertical front edge and the straight side skirt with steep cut back-edge shows a tendency of decreasing benefit with increasing yaw angles, fig.8. At larger yaw angles the flow can not handle the sharp vertical edge without immediate separation of the local flow. Rounding-off the sharp edges with half circles made of foam should give a drag benefit.

Three different set-ups were tried: the half circles on the inside, fig.13(a), on the outside only, fig.13(b) and on the in- and outside. The situation with the half circles on the outside, fig.12, performed worst over the range of yaw angles: at a yaw angle of zero degrees the flow has to overcome an extra obstacle which causes more drag and at a yaw angles of \(6 - 10^\circ\) the flow separates on the inside causing drag. With the half circles on the in- and outside one can notice in fig.12 a slight improvement in drag benefit at the higher yaw angles. The best of the three configurations is obtained with the side skirt which has the half circles on the inside. At a yaw angle of zero degrees this solution produces 11\% less drag in comparison to the base configuration instead of 7\% for the other two, see fig.12. Also with increasing yaw angles for the side skirt with half circle on the inside increasing benefits are obtained in comparison to the ones with the half circles on the outside.

The half circle is not an ideal aerodynamic shape in this case, therefore an airfoil profile (patent pending) was mounted at the front inside. With the profile a drag reduction of 14\% or \(\Delta C_T = -0.061\) at zero degrees yaw angle and a maximum of 16\% (\(\Delta C_T = -0.069\)) at a yaw angle of 8\(^\circ\) is obtained which is considerably more than with the half circle at the front, fig.12. With this profile at the inside of the front edge the flow does not separate at the edge and causes a lot less aerodynamic drag.

### 3.3 Add-on: underbody

The second group of aerodynamic add-ons consists of the so-called underbodies. The measured drag benefit of the complete underbody, fig.15(a), is plot in fig.14: it generates at zero yaw angle 7\% less drag (\(\Delta C_T = -0.030\)) and 12\% or \(\Delta C_T = -0.052\) at 6\(^\circ\) yaw angle.

A second version of the underbody had covered wheels, fig.15(b), to show their influence on the drag coefficient \(C_T\). Fig.14 demonstrates again that better results were achieved with the
wheels covered: a decrease of 3% ($\Delta C_T = -0.013$) of the drag coefficient with respect to the similar configuration with the open wheels. Once more the results show that the wheels are a source of extra irregularities and thus drag. This increase of 3% was also found with the straight side skirt with the uncovered wheels which can be noticed in fig. 8.

The last variation is the underbody with covered wheels but without the diffuser, fig. 15(c). This modification improved the results marginally. A possible reason for the fact that the configuration without the diffuser works better than with the diffuser can lie in the fact that the diffuser is probably badly designed for this model set-up: a wrong diffuser angle initiates flow separation.
4 DISCUSSION

Fig.16 presents an overview of $\Delta C_T$ of the best performing aerodynamic add-ons selected from the group of the side skirts and the underbody. During the different wind tunnel tests it turned out that covering the wheels is always beneficial for the drag coefficient and blocking the underbody flow is disastrous for $C_T$. A full underbody that covers the support legs, pallet box and the axles of the wheels is not performing as well as the straight side-skirts which comprises two single panels along the lower side of the trailer in longitudinal direction. Modifications to these side-skirts improved the drag reductions even further up to 14% which corresponds with a $\Delta C_T$ of -0.062. The round front side skirt has a $\Delta C_T$ of -0.055 at zero yaw angle, but its efficiency drops when it reaches a yaw angle of 6°, while the side skirt with the profile has still an increasing $\Delta C_T$ above 6° yawing angle.

![Figure 16: Overview $\Delta C_T$ results](image1)

![Figure 17: Trailer $\Delta C_{p,back}$ results](image2)

![Figure 18: Overview $\Delta C_{p,back}$ results](image3)

![Figure 19: Ratio between $\Delta C_T$ and $\Delta C_{p,back}$](image4)

Fig.17 as well as fig.18 shows that changes in $\Delta C_T$ are not directly related to changes of the corresponding pressure coefficient at the back surface of the trailer. The difference in pressure coefficient in terms of percentage is obtained according to eq.2 below:
\[
\Delta C_{p,\text{back}} = \frac{C_{p,\text{mod}} - C_{p,\text{ref}}}{C_{p,\text{ref}}} \cdot 100
\]

\(C_{p,\text{ref}}\) is the average pressure coefficient at the back surface of trailer with the rounded front corners, while \(C_{p,\text{mod}}\) is the average pressure coefficient at the back of the related modified trailer. A negative \(\Delta C_{p,\text{back}}\) in terms of percentage corresponds with a less negative \(C_{p,\text{back}}\) (a lower suction force) of a trailer equipped with an aerodynamic aid with respect to the \(C_{p,\text{back}}\) of the reference trailer. The relation between the two quantities, \(\Delta C_T\) and \(\Delta C_{p,\text{back}}\), is in addition a function of the yawing angle. Considering fig.17, only the totally blocked back-end configuration demonstrates a comparable behavior, but the difference in terms of percentage of the pressure coefficient decrement is double compared to the drag increase. Removing the mud flaps around the wheels results in a drag decrease of the vehicle but results in a more negative underpressure at the back surface.

All the aerodynamic devices in fig.18 are showing rather the same influence: at zero yaw angles there is a certain benefit, a less negative \(C_{p,\text{back}}\), only the amount of this benefit in terms of percentage is dependent of the corresponding aid. This benefit is constant or slightly increases over the range \(2^\circ - 4^\circ\) and then decreases with yaw angles above the \(4^\circ\).

The side skirt with the sharp front, fig.9(c) performs the best in terms of pressure coefficients increase which can be regarded in fig.18. While this configuration was responsible for a drag coefficient decrease of 12\% which was less than the straight side skirt with the profile: 14\%.

According to Rose [13] this drag reduction corresponds with a fuel economy decrease of 7\% at high way speeds.

Fig.19 shows the ratio between \(\Delta C_T\) and \(\Delta C_{p,\text{back}}\). One can notice that the changes of respectively \(\Delta C_T\) and \(\Delta C_{p,\text{back}}\) for the side skirt with the sharp and round front are over the range of yaw angles rather constant and positive. The latter signifies that the change in pressure coefficient did not switch of sign. All the \(\Delta C_{p,\text{back}}\) of the other aerodynamic aids switch of sign. It is not easy to understand why the benefit in terms of percentage is decreasing with increasing yaw angles without proper flow investigation techniques to determine the flow behavior. Literature also does not provide an explanation for this mechanism, apparently the relation of the change of pressure coefficients with the yaw angle has not been investigated yet.

The above discussion illustrates that changes in drag and pressure coefficients are not directly interrelated with the different configurations and aerodynamic aids. For two dimensional airplane profiles the wake, its size and the local pressure are measure for the total drag which include the friction and the pressure drag of that profile. The above results indicate a different behavior for bluff bodies. Of-course a truck is a bluff body, other flow mechanisms could be expected. One has to remark that the pressure coefficients are measured at the back of the trailer and they give an indication of the pressure drag with respect to the back of the trailer. There are other regions on the truck which are contributing to the total pressure drag of the vehicle like the front and the back of the tractor and the front and the back of wheels, pallet box, etc. This may be a reason why the benefits
in drag coefficients are not immediately translated in pressure coefficients benefits measured at the back of the trailer. Therefore one can state that the tested aerodynamic aids provide the best local drag reduction and that depending on the aerodynamic aid the drag benefit is translated to a pressure coefficient benefit at the back of the trailer.

An attempt has been made to verify these statements with a simple test. With two thin big and small plates mounted vertically at the front of the trailer, see fig.20, separation of the boundary layer is initiated. Fig.21 and fig.22 show the drag and pressure coefficients respectively for the trailer with both separation plates. The plates cause a higher drag coefficient: 20% for the small plate but up to 70% more drag for the big plate, fig.21. But both plates have a positive influence on the pressure coefficient: a reduction of 4% and 6% for the small and big plate respectively at zero yaw angle. Although the separation plates have a big negative influence on the drag coefficient, it is not translated in an equivalent negative influence on the pressure coefficient at the back of the vehicle. A straightforward explanation for this fact is hard to give without proper visualization tools. An increase of $C_T$ is not immediately translated in a more negative $C_{p,back}$. According to Duell and George [6] a complex play of boundary and shear layers at the back end of bluff bodies gives an answer to this behavior. Further investigation is opportune to clear out the above statements.

5 CONCLUSION AND RECOMMENDATIONS

With the aid of wind tunnel tests an aerodynamic aid was developed for the lower region of the trailer which reduces the drag coefficient significantly. The model used for the wind tunnel tests is adapted: a smooth tractor cabin and rounded front trailer edges are added. The sharp edges of the cabin are successfully rounded to prevent separation of flow around the cabin. The suspension of the model in the wind tunnel test section is such that the thickness of the boundary layer of the ground board is reduced to a minimum. The measuring velocity in the wind tunnel is set at 60m/s due to the low sensitivity of Reynolds effects of the model and the high aerodynamic forces at higher wind tunnel speeds. The Reynolds number used in the tested is within the region defined by the SAE. The drag coefficient stays constant with increasing speed.
Both facts underline that the chosen measuring velocity is sufficient to perform the tests.

The research was focused on two different types of aerodynamic aids: the side skirt and the underbody principle. The drag force of the total vehicle and the pressure at the back of the vehicle were measured to investigate the influence of the different aerodynamic aids. In total more than 100 different configurations are tested in the wind tunnel. The configurations with the straight side skirts and profile generated the highest drag reductions: up to 14%. This can be translated in a fuel economy reduction of 7%. The reasons that this new aerodynamic add-on reduces the drag further then standard side skirts can be found in the fact that the locally applied modifications prevent flow separation at the sharp vertical edge of the normal side skirt at yaw angles higher than $0^\circ$. Numerical analysis of the truck model with the new aerodynamic aid should clarify the total drag decrease of the vehicle and make it possible to optimize and increase the efficiency of the device.

Pressure measurements are performed at the back of the trailer for all the different configurations in order to gather more information about its mutual relation. Just like the drag coefficient, the pressure coefficient stays constant with increasing Reynolds number: no Reynolds effects are occurring. The comparison of the pressure coefficients between the different trailer configurations revealed other results with respect to the corresponding values and behavior of the drag coefficient differences. A reason for these differences is that the corresponding aerodynamic aid reduces the drag locally and that this is not always translated into a pressure coefficient benefit at the back of the vehicle. Aerodynamic devices as for example side skirts do not only influence the pressure drag of the back but apparently also other parts of the flow. Proper breakdown of the different (pressure) drag contribution of the model (front, middle and rear) with the aid of numerical analysis of generalized vehicle together with flow visualization and other measuring techniques should help with gathering a more fundamental insight in the flow mechanisms in the wake of bluff bodies to design a second generation of aerodynamic add-ons with an even higher fuel efficiency.
REFERENCES


