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AERODYNAMIC EFFECTS ON B-TRAIN TRACTOR-TRAILER CONFIGURATION AND DRAG REDUCTION WITH AERODYNAMIC DEVICES

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Abstract: The present interest of lessening the fuel utilization of vehicles is standout amongst the most difficult issues inside the Automotive Industry. An ongoing exploration about fuel decrease advancements for trucks demonstrated that streamlined enhancement is a significant step amongst the most vital advances with regards to fuel sparing. Beforehand, examine has been done in this field with the extension constrained to customary Tractor Trailer course of action. The present study deals with Aerodynamic effect on B train tractor trailer configuration
Keywords: CAE, CFD, Aerodynamics, Trucks,

I. INTRODUCTION

The present interest of lessening the fuel utilization of vehicles is a standout amongst the most testing issues inside the car business. Together with the expanded fuel value, the advancement of more fuel efficient vehicles has heightened. An ongoing examination about fuel decrease advances for trucks demonstrated that streamlined improvement is a standout amongst the most vital advances with regards to fuel sparing. Previously, research has been carried out in this field with the scope limited to conventional Tractor Trailer arrangement. This Project deals with the Aerodynamic drag effect on various Aerodynamic trailer devices in B Train configuration when running in platooning arrangement. Different streamlined trailer contraptions and productively shaped trailers have been attempted by strategies for Computational Fluid Dynamics, in order to inspect their influence on the flow around the truck. The tests was copied with a speed of 90 km/h, and with yaw edges of 0°, 5° and 10˚. What's more, drag commitment from different areas was broke down to see where it is conceivable to increase most drag decrease. At long last, an assessment was done to check whether the outcomes from the reproductions could advance any conceivable streamlined profits of a common improvement among tractor and trailer makers. The scope of project has been broadened to B-Train in contrary to previous research which were been carried out limited to conventional Semi Trailers. The Cab over Engine model and class 8 which mostly ply in US and European Union respectively have been taken into account to study the comparison of drag on frontal area of the heavy duty truck.

II. CASE DEFNITION

The vehicle combination that was the basis for this investigation was a combination that consisted of a tractor with two trailers in tandem, In B-Train configuration. Two models were chosen as Tractor, first one was with TATA prima Tractor and second one as a Class8 tractor. The total length of the vehicle combination was 32m and 36m respectively. Both Tractors were equipped with Aerodynamic devices like roof deflector, cab side-extenders and chassis skirts. The gap sizes between the cab and 1st semi-trailer and between the 1st and 2nd semi-trailer was 0.65m and 1.48m, respectively. The reference frontal area of the vehicles, which was used to calculate the drag coefficients was $10.2m^2$, including the rear-view mirrors.

Importance of Chassis Skirts and Gap Treatment:

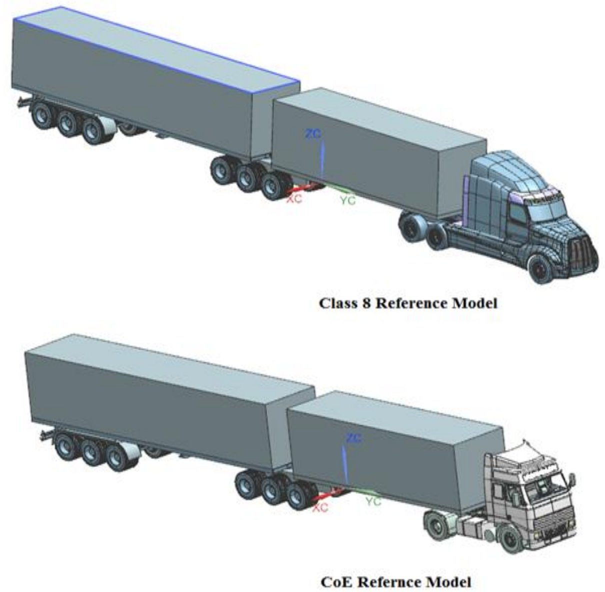

Fig 1

As it was observed in above image, both the gap between two trailer units are bare and exposed chassis of the trailers are two large sources of the aggregate drag of the vehicle combination, strategies for reducing their impact have been investigated. The different vehicle configurations evaluated in this investigation are presented below. The reference vehicle geometry was modified in the gap region between the semi-trailer units and along chassis level. Two different strategies for the gap treatment were investigated: a covered gap and an eliminated gap, where the two B-trailer units were simply pulled together.

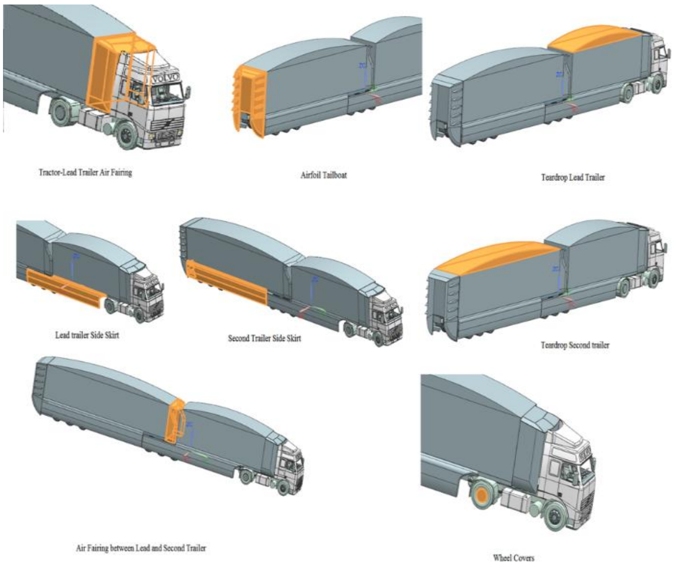

Fig 2: Case1

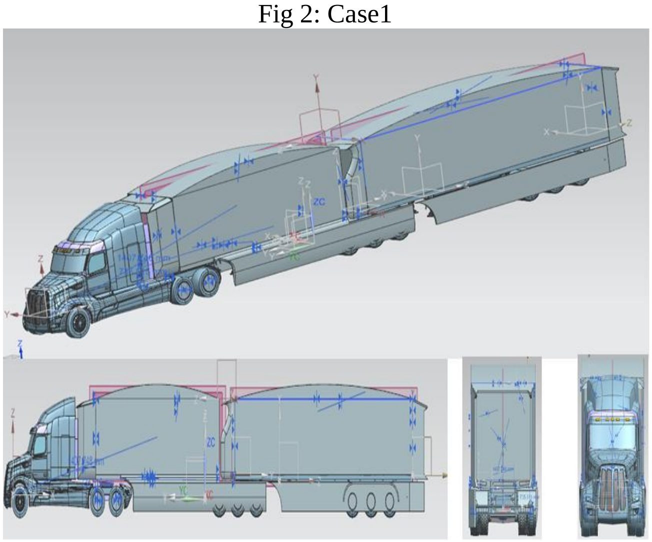

Fig 3: Case 2

Above Figure shows 2 Cases, the configuration with a covered gap between the trailers. Case 1 is shown in Figure 2 and was the configuration with chassis skirts along the semi-trailers. The chassis skirts covered a large part of the otherwise bare under-body of the trailers. The chassis skirts for the 1st trailer also covered the already existing chassis skirts for the tractor: to obtain a smooth shape along the sides. Also the wheel housings of the trailers and the rear wheels of the tractor were covered, to eliminate the main part of the turbulent structures originating from the wheels.

In the analysis performed for the ideal design changes, adjustments of the geometries were only made for the trailer units and the gap region between the trailers. The cab was left unmodified and also the gap between the cab and the first trailer unit. All modifications here were rather ideal; practical technical solutions for solving the gap coverage or chassis skirts have not been investigated at this stage. The intention was to investigate the potential for aerodynamic reductions by working with the gap and chassis region.

Airfoil tail boat

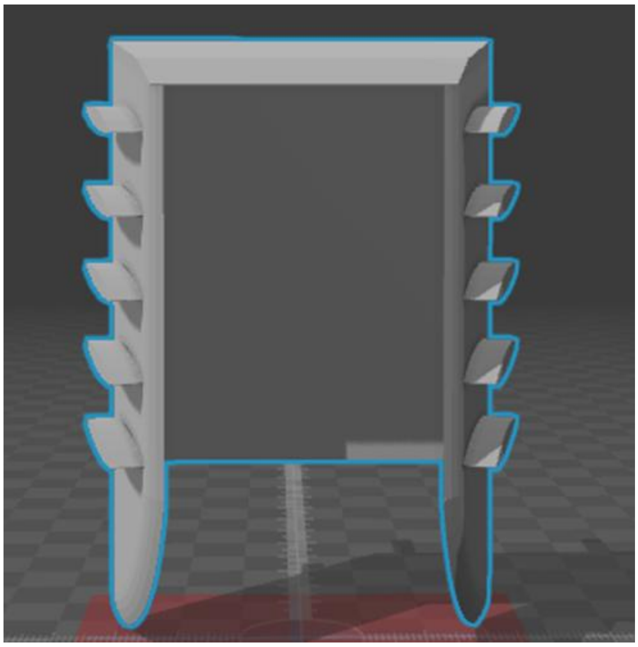

Fig4: Airfoil tailboat

Streamlines wind current at the back of the trailer is utilized to lessen the low-weight vacuum that makes back drag and diminished eco-friendliness and it does as such without obstructing trailer payload limit, stacking or emptying. A new concept of adding Airfoils on Tailboat was conceptualized and implemented in order to study its effect and on Vortex formation and wake at rear of vehicle. This plays a crucial role as rear of the vehicle has a tendency to pull back the vehicle at the rear due to the formation of Vacuum at rear. The Airfoil concept inspired from Aeroplanes was implemented to reduce this wake and vortex formation. This is entirely a new concept and has never been researched particularly on a Tailboat Aerodynamic device.

Trailer side skirt

A trailer skirt or side skirt is a gadget joined to the underside of a semi-trailer, to reduce streamlined drag brought about via air turbulence under the trailer. A 2012 examination by SAE International of nine trailer skirt plans found that these gave fuel reserve funds more prominent than 5%, contrasted and an unmodified trailer. Skirts with diminished ground leeway offer more prominent fuel savings.

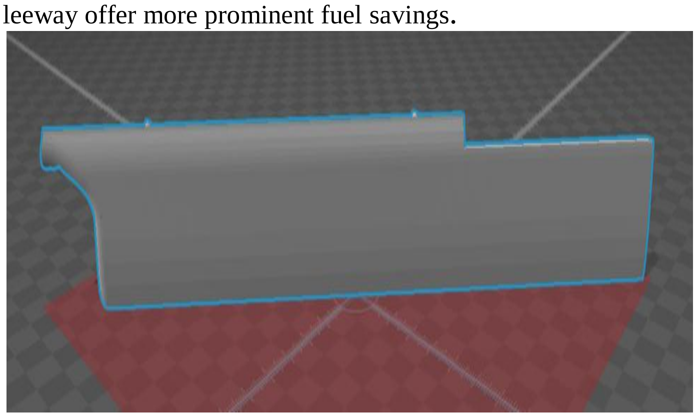

Fig 5: Skirt

Teardrop

The Teardrops of both trailer have been designed in correspondence to provide excellent streamlined flow above trailer roof. By CFD simulation, it was observed that there is a certain vortex formation on top of trailer which originated from trailer starting edge and considerably increases along its length. This leads to the additional drag on trailer surface roof. This is minimized by Teardrop. The Teardrop are designed with 10˚ inclination from roof base. This prevents vortex formation along roof surface and streamlines the flow.

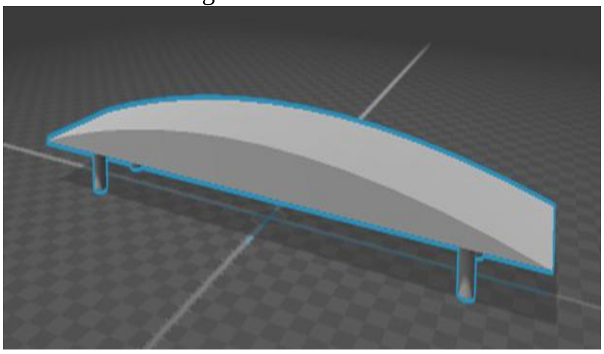

Fig 6: teardrop

Practical Gap Fairing Device

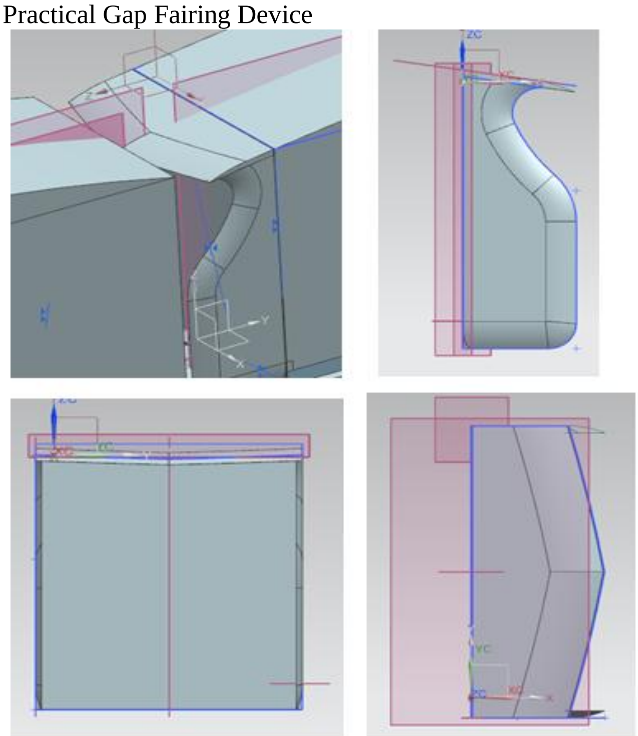

Fig 7: Gap fairing

The inclusion, or end of the hole between the trailers are perfect arrangements of the hole treatment. So as to accomplish a comprehension of the execution of a more reasonable arrangement of this issue, an alleged hole fairing framework was researched. It is a gadget that had smooth, adjusted edges, which was mounted on the front essence of the trailer and its motivation was to lessen the high-weight zone at the edges of the trailer, and rather control the stream onto the trailer rooftop and sides and thus improve re-connection of the stream. The hole fairing also reduced the gap size where it operated. A picture of the gap fairing device mounted on the trailer front face can be seen in Figure 7.

NUMERICAL SET-UP

CAE based investigation was done to study this case. The method used in this investigation was Computational Fluid Dynamics [CFD]. CAD cleaning and initial surface meshing was performed in NX CAD software and Ansys Mesh respectively. while the models was volume meshed and run in Ansys Fluent as solver.

Mesh

Open-road conditions were used for the computational domain, i.e. the wind tunnel domain was very large in order not to affect the simulation results. The extension of the calculation domain was 2.5 times the combination length upstream of the vehicle and 5 times the combination length downstream of the vehicle, in the longitudinal direction. In the lateral direction, the domain was 12 times the vehicle width in total, and in vertical direction 5 times the vehicle height. The longest vehicle combination was used for dimensioning the size of calculation domain, and its extension was based on recommendations from SAE J2966. Closest to the vehicle surface, prism layers were created to capture the viscous effects of the flow near the wall. For surfaces where mainly attached flow was predicted, 3 layers with a total height of 6mm were created, while for the other parts, one layer with a height of 1mm was defined both near and more distant from the vehicle surface there were different levels of refinement in the volume mesh, in order to better resolve regions where interesting flow phenomena were found. Two main refinement levels were defined around the entire vehicle combination, plus a separate refinement zone in the base wake area. In the gap between the semi-trailers and around the roof deflector and cab side-extenders, the mesh was even finer. Also, the front grill area was refined in order to better resolve the forward stagnation region.

III. SIMULATION

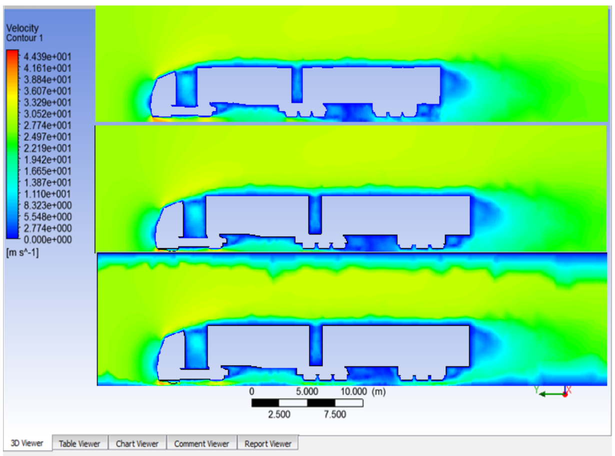

Fig 8: Velocity contour for 0^0, 5^0 and 10^0 yaw angle for case 1

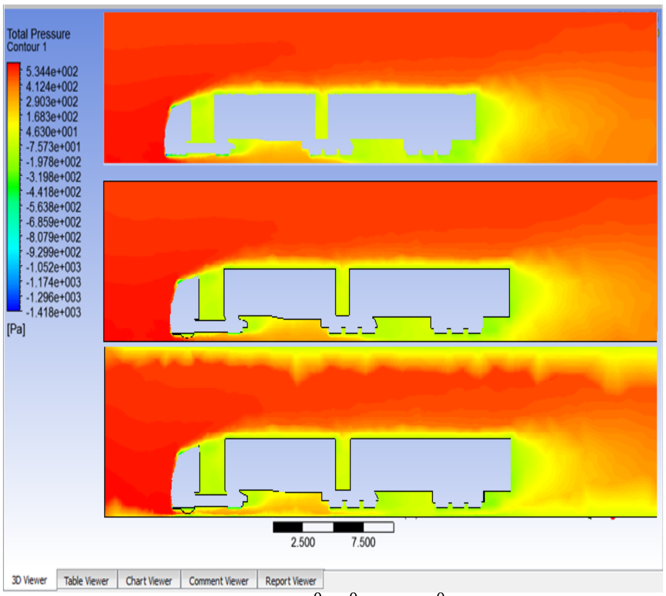

Fig 9: Pressure contour for 0^0, 5^0 and 10^0 yaw angle for case 1

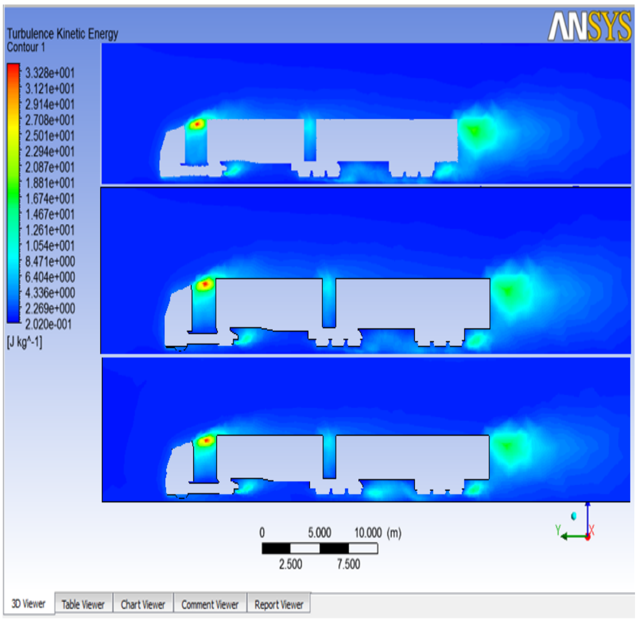

Fig 10: Turbulent Kinetic Energy contour for 0^0, 5^0 and 10^0 yaw angle for case 1

The simulations that were run were based on the Reynolds-Averaged Navier-Stokes approach [RANS]. The turbulent properties of the flow were modelled by using the realizable k-ε two-layer turbulence model. The reason for choosing this model was that it offers considerable mesh flexibility, and it can be used both for meshes solved for High-Reynolds Number models, as well as for meshes where a Low-Reynolds Number approach is conducted. This model also produced the least inaccuracies for meshes where l<y +<30 [20].

The simulations were run assuming moving ground, in order to achieve realistic boundary conditions. The inlet of the calculation domain was modelled as velocity-inlet, the outlet as pressure-outlet, and the side and top walls were modelled with a wall-slip condition. The free stream velocity was 90km/h, corresponding to normal European highway driving conditions. Simulations were run both in 0°, 5° & 10° yaw, in order to investigate the effects of side wind on the tested configurations. This was necessary since the aerodynamic properties of trucks change considerably in side winds; especially for vehicle combinations with multiple cargo-units.

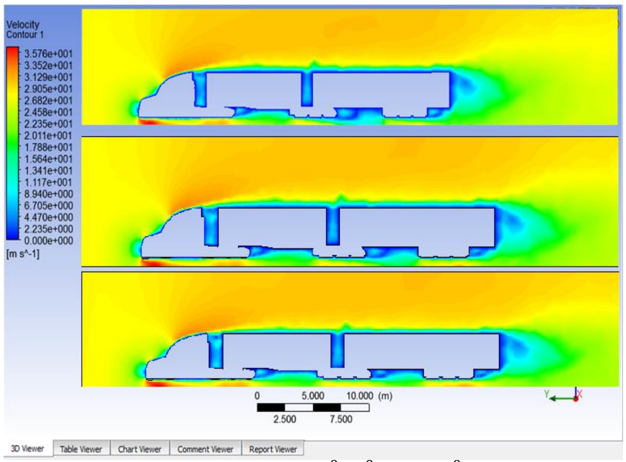

Fig 11: Velocity contour for 0^0, 5^0 and 10^0 yaw angle for case 2

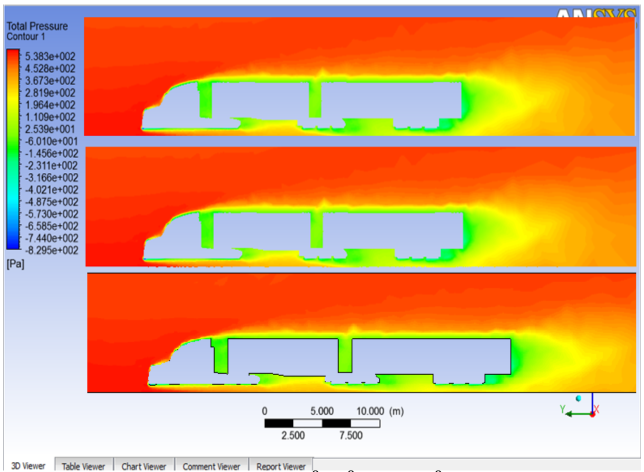

Fig 12: Pressure contour for 0^0, 5^0 and 10^0 yaw angle for case 2

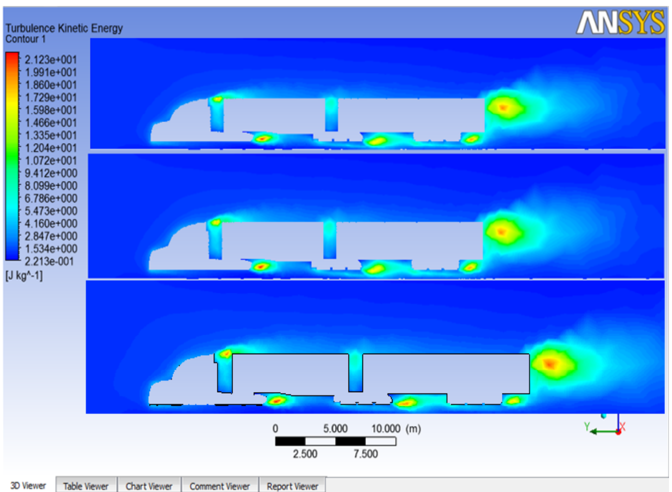

Fig 13: Turbulent Kinetic Energy contour for 0^0, 5^0 and 10^0 yaw angle for case 2

The meshing approach was slightly different for the 5° yaw cases; the entire calculation domain was rotated 5° and the mesh was then reproduced with the wind tunnel as the reference coordinate system. In this manner, the free stream would flow axially in- and out of the computational cell. The right-hand side, seen from the truck driver's perspective, was the windward side in the simulations.

RESULTS

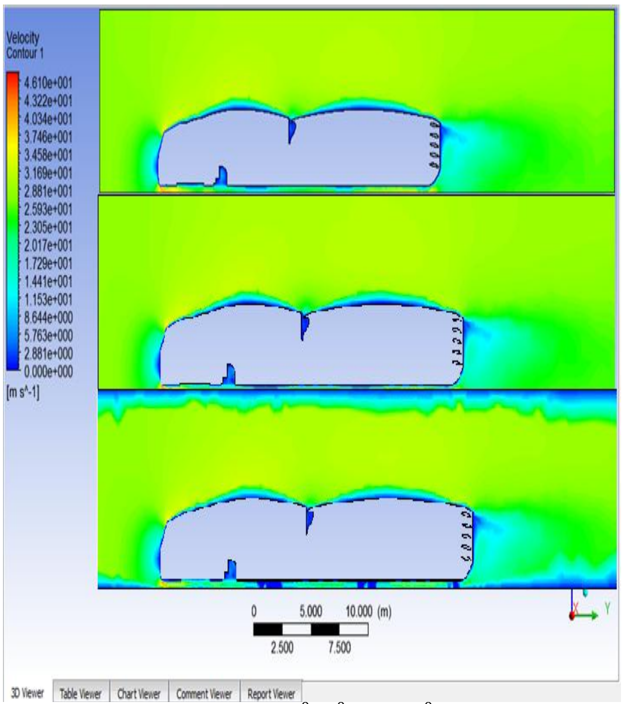

Fig 14: Velocity contour for 0^0, 5^0 and 10^0 yaw angle for case 1

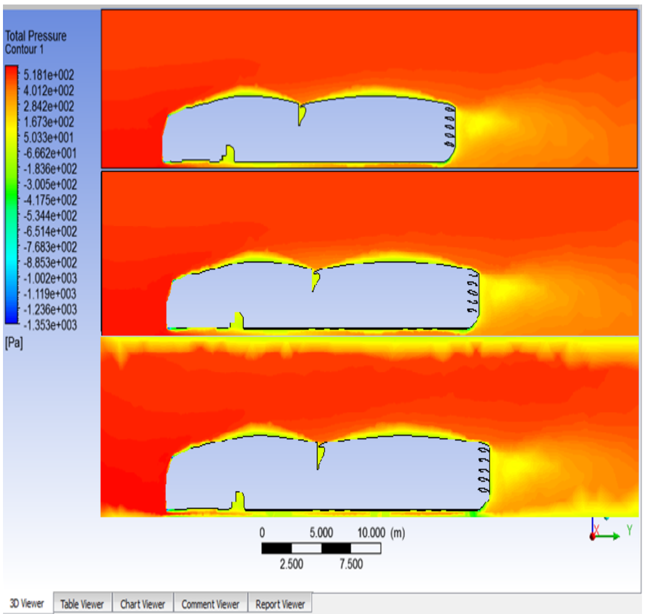

Fig 15: Pressure contour for 0^0, 5^0 and 10^0 yaw angle for case 1

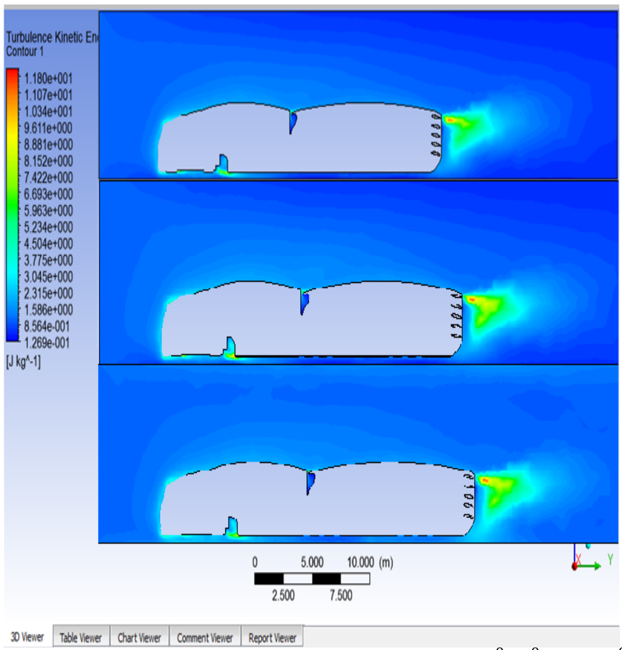

Fig 16: Turbulent Kinetic Energy contour for 0^0, 5^0 and 10^0 yaw angle for case 1

Effects of Chassis Skirts and Gap Treatment on Drag

The results from the investigations showed that it was beneficial to make adjustments to the gap- and chassis region on the vehicle combination. Especially in 5° yaw conditions the drag reductions were considerable. Above figures shows the difference in drag, in 0° yaw, compared to the reference case for the ideal design changes. From Figure 16 it can be seen that all efforts to reduce drag for the vehicle combination were successful; but as can be seen, the levels of the drag reductions were rather modest; at least for the gap covering and gap elimination. A combined solution with eliminated gap and chassis skirts yielded a drag reduction of more than 0.04; the combined effect being larger than the individual contributions added together. This indicated that a more favourable flow field has been achieved around the vehicle with less disturbed flow. The results indicated that it was slightly more favourable to eliminate the gap, compared to covering it. The same effect was seen for the combined solution with chassis skirts and gap treatment, where Case 1&2 showed a larger drag reduction. The figure also shows the corresponding results from the 5° and 10° yaw simulations. The results from the 10°. and 5° yaw reenactments demonstrated that the drag decreases were extensively bigger than in 0° yawed breeze. This impact was especially solid for the mixes with suspension skirts (Case 1C, ID and IF]. The drag decreases for cases with hole disposal or hole inclusion (Case IB and IE] was roughly twofold the sum contrasted with 0° yaw, yet contrasted with the frame skirts arrangements those outcomes were fairly unassuming. For a consolidated arrangement of undercarriage skirts and hole disposal the drag decrease was in the scope of 0.25, which is extremely huge. The explanation behind the aftereffects of the case skirts being progressively unmistakable was that, in yawed-wind conditions, the body skirts protected the primary piece of the sporadic skeleton of the semi-trailer units. Since the vehicle blend was more than 30m long, the impact of such a gadget turned out to be substantial. It was also detected that the combined effect of chassis skirts and gap treatment was larger than the individual contributions added together, just as in 0° yaw. The trend which was seen in 0° yaw was also consistent in 5° and 10° yaw; it was slightly more efficient to eliminate the gap compared to covering the gap, also for the combined treatment of the gap and chassis skirts. Hence, all trends that were seen were consistent between all cases and yaw conditions.

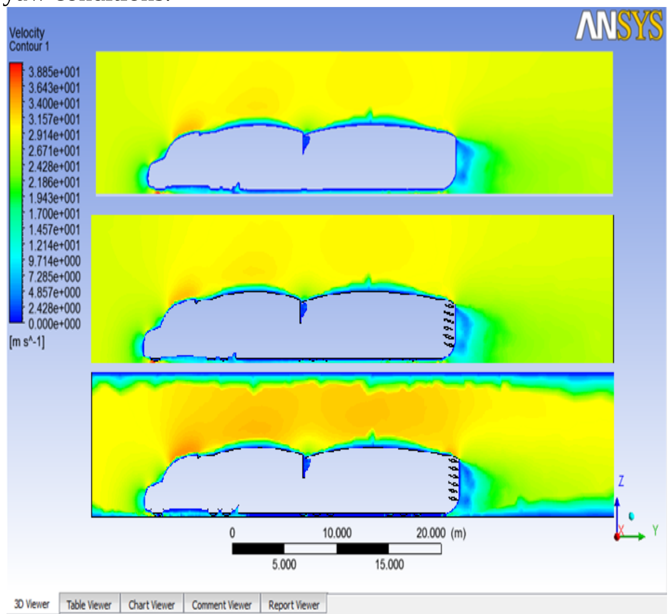

Fig 17: Velocity contour for 0^0, 5^0 and 10^0 yaw angle for case 2

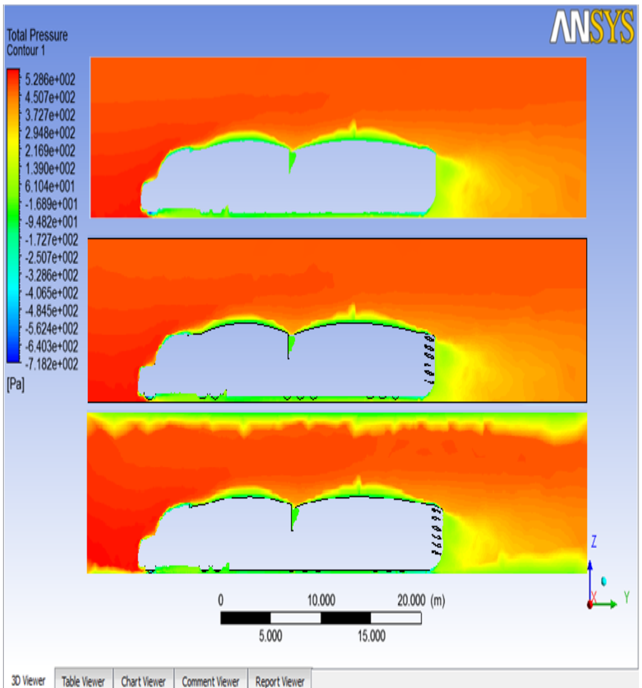

Fig 18: Pressure contour for 0^0, 5^0 and 10^0 yaw angle for case 2

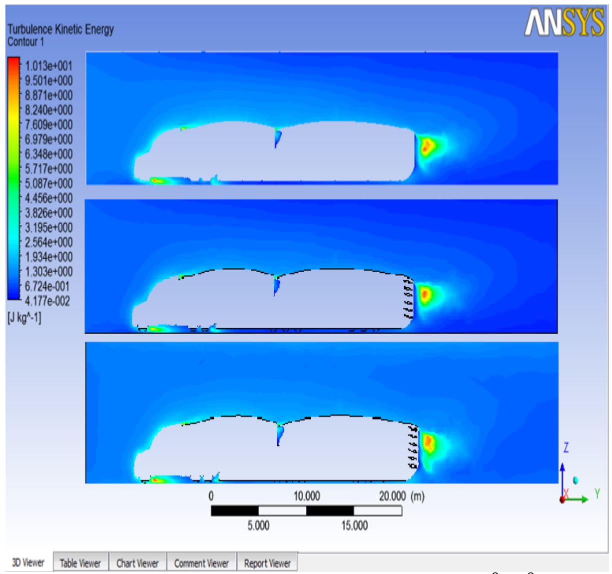

Fig 19: Turbulent Kinetic Energy contour for 0^0, 5^0 and 10^0 yaw angle for case 2

A more practical solution of the gap treatment was investigated; the so-called gap fairing. The results from the simulations with gap fairings also showed drag reductions from the reference configuration, and the results for the simulations are shown in Figure 19. There was a drag reduction of almost 0.013 when adding the gap fairing to the 1st semi-trailer. Adding a fairing system also to the 2nd semi-trailer resulted in a total drag decrease of 0.015. Comparing the numerical values to configuration without aerodynamic devices, the cases with either covered or eliminated gap between the trailer units, it was seen that approximately the same drag reduction could be obtained with other case too, given that the device is mounted on both semi-trailer units. However, having the gap fairing mounted to the 2nd semi-trailer only, did not affect drag in a positive way. On the contrary, drag was slightly increased in 0°yaw. CD was increased by 0.0015 so the effect of the rear gap fairing was not efficient if mounted alone. Though, the increase was not very significant.

The results from the 5° yaw simulations, shown in Figure 17. The results from the 5° yaw simulations showed approximately the same results as the ideal solutions for the rear gap treatment in 5° yaw. Just as in 0° yaw, it was confirmed that it was beneficial to install the practical gap fairing device. Also for these wind conditions, there was a slight advantage associated with having both semi-trailers recovered as the flow reached the trailer roof. The recovery of drag on the leading edge of the 1st semi-trailer can be explained by the pressure level on the front face of the trailer was lower than in the surrounding air. Hence, the cab-side extenders and roof deflector were efficient in reducing drag in this area. Furthermore, it was possible to detect another important area for drag accumulation; the area around the wheels appeared to contribute significantly to the drag accumulation. In each area where the wheels were situated there was a strong drag accumulation, especially for the 2nd semi-trailer unit. Even though the overall appearance of the drag accumulation curves were similar between the cases, it was possible to distinguish between the behaviour of the different configurations. It was clear that the cases without any gap treatment had a fairly steep increase in drag in the gap region. It is clear that the effects of the gap region became larger when having improved the flow field by means of chassis skirts. The drag reduction was locally interrupted in the gap region in original cases, with a significant drag increase, after which the reduction was continued along the 2nd semi-trailer where chassis skirts were added. Compared to the behaviour of original case, where the gap between the trailers was covered, there was a significant further drag decrease in the gap region compared to the reference configuration. Comparing the pressure levels on the front face of the 2nd semi-trailer for Case 1A and 1C, confirmed that the pressure was higher for Case 1C, also supported by numerical values for the local drag on this part. This confirmed the fact that more air flowed into the gap and interacted with the 2nd trailer. It seemed that the pressure on the upper part of the 2nd semi-trailer front face increased compared to the reference configuration. This means that the flow was redirected over the vehicle combination and a larger part of the flow was entering the gap from the top of the trailer. Hence it also indicated that less air entered the gap via the lower part of the gap; the flow field was redistributed as a consequence of the chassis skirts. While adding the hole fairing to the semi-trailer front, it was seen that the high-weight regions on the edges of the trailer front countenances were generously diminished. This impact was seen for both the front and back semi-trailer units. Consequently, this suggests the stream was all the more easily guided towards the sides of the trailer. The arrangement with back hole fairing just, brought about a slight drag increment contrasted with the reference case. It very well may be seen that drag was recouped locally soon after the hole fairing on the second semi-trailer unit, however this drag decline was step by step decreased towards the finish of the second semi-trailer, and the net impact was that there was a little drag increment. However, the expansion in drag of 0.0015 was extremely little and can't be viewed as a critical outcome, rather that the impact of the hole fairing framework in this arrangement was immaterial the case with hole fairing framework on both trailer units, demonstrated a similar pattern along the second trailer unit as the drag decline got in the hole between the trailer units was diminished towards the end, showing that the stream was diverted in a troublesome way with the hole fairing and subsequently a portion of the drag decrease was lost downstream. The ideal chassis skirts analyzed here seemed to work efficiently in yawed-wind conditions; blocking the main part of the flow which otherwise would interact with the irregular chassis of the trailers. Also the extensive regions originating from the wheel rotations were cancelled out. There was still an area of high pressure around the dolly; since the air had the possibility to flow from the chassis skirts in through the gap, and interact with the dolly wheels and under-body. This phenomenon was reduced to a minimum for Case with aerodynamic devices, where the gap was eliminated. 43% drag reduction for COE (Can Over Engine) and 45% drag reduction was obtained for Class8 configuration. There were no longer significant areas of high pressures on the under-body; for a large part of the bodies the pressure was close to the surrounding pressure, which helped to reduce drag for this configuration.

IV. CONCLUSION

- Aerodynamic trailer gadgets have an incredible capability of diminishing drag. Contrasted with the tractor, the trailer is much more susceptible for aerodynamic drag improvements and thus the fuel consumption can be substantially reduced by using trailer devices
- The tractor already has a relatively good aerodynamic shape and adjustments are limited. Therefore, to achieve further aerodynamic improvements, and thereby reduce the fuel consumption and emissions, the next step for companies should be to consider the whole truck during the aerodynamic development. In order to do this, a co-operation between the tractor and trailer manufacturers is recommended and communication between these two should be established.
- The advantage if the tractor and the trailer were to be developed together especially applies to the interface between the cab and the trailer front, but also between the chassis and trailer underbody. A mutual development would make it possible to optimize the integration of these components, which would improve the flow transition and thereby improve both the undercarriage flow and the base flow.
- Class8 configuration gives more drag reduction due to its pointed front face which enhances the streamline flow of air and prevent air gust towards central portion of vehicle front.
- The gadgets Side skirts and Frame augmentation have amid this undertaking appeared substantial potential to improve the stream in these areas and ought to be of incredible enthusiasm for further advancement.

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