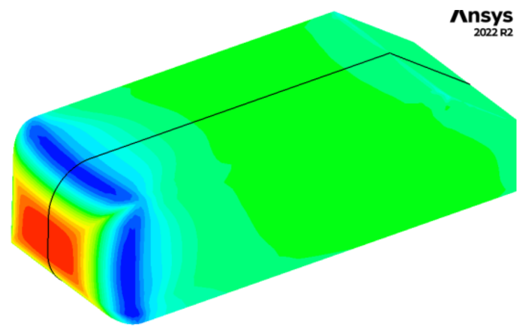
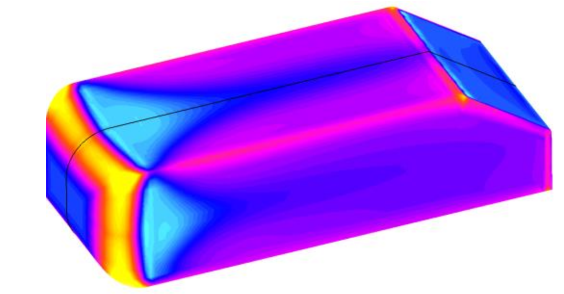


Ahmed Body: Optimization of rear slant angle and influence of frontal aspect ratio on total drag



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Introduction:

The flow dynamics of Ahmed Body (generic car model) was studied using Computational Fluid Dynamics approach (CFD) with the aim to optimize the real slant angle to achieve minimum total drag. Subsequently, the influence of frontal aspect ratio on the total drag was investigated for two angles. The validation for 35 [deg] angle was done against the available Large Eddy Simulation (LES) data.

Methods:

Geometry: The 1:4 size of original model [1] of Ahmed Body using symmetry with Fig.1 dimensions.

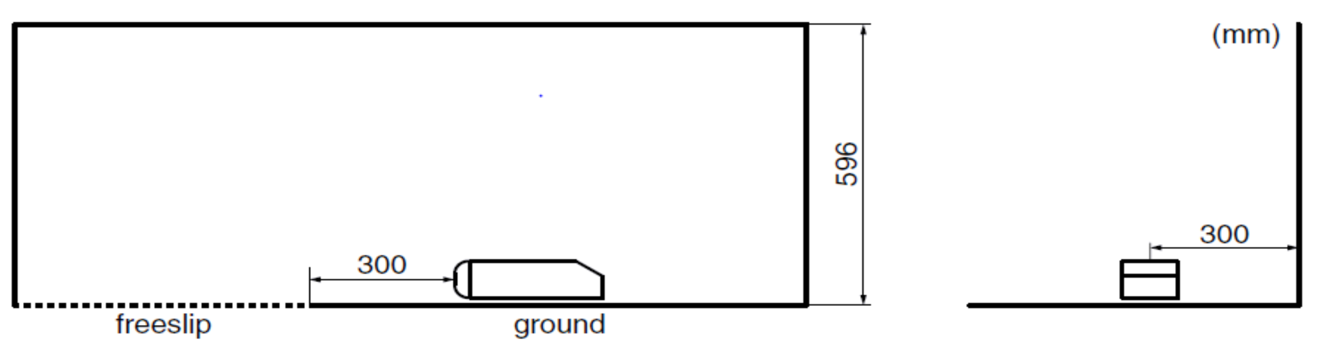
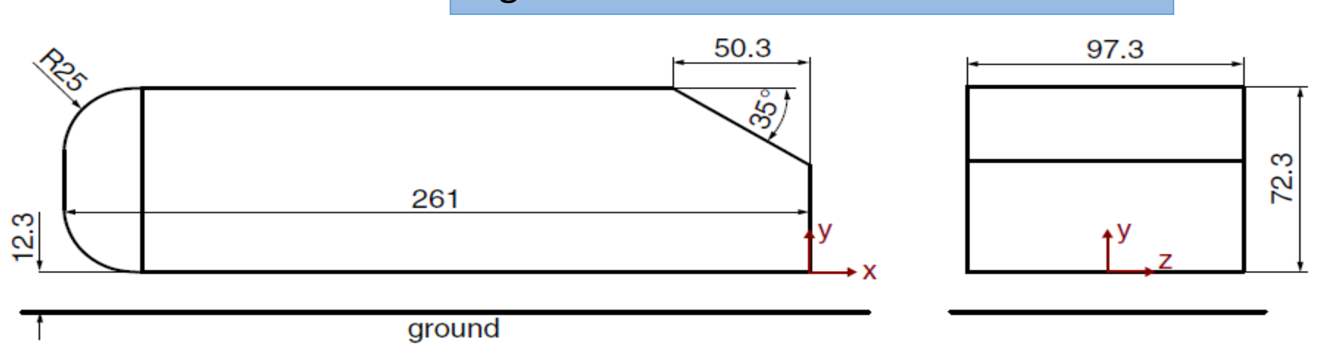


Fig.1: Geometric & domain dimensions.



Mesh: Good mesh quality with 455.5K nodes, using inflation y+ < 1 (car surface) and y+ < 5 (ground) was achieved for implementation of SST k-ω (RANS) with 1st order & High-resolution scheme at $Re_{\sqrt{A}}$ =30000.

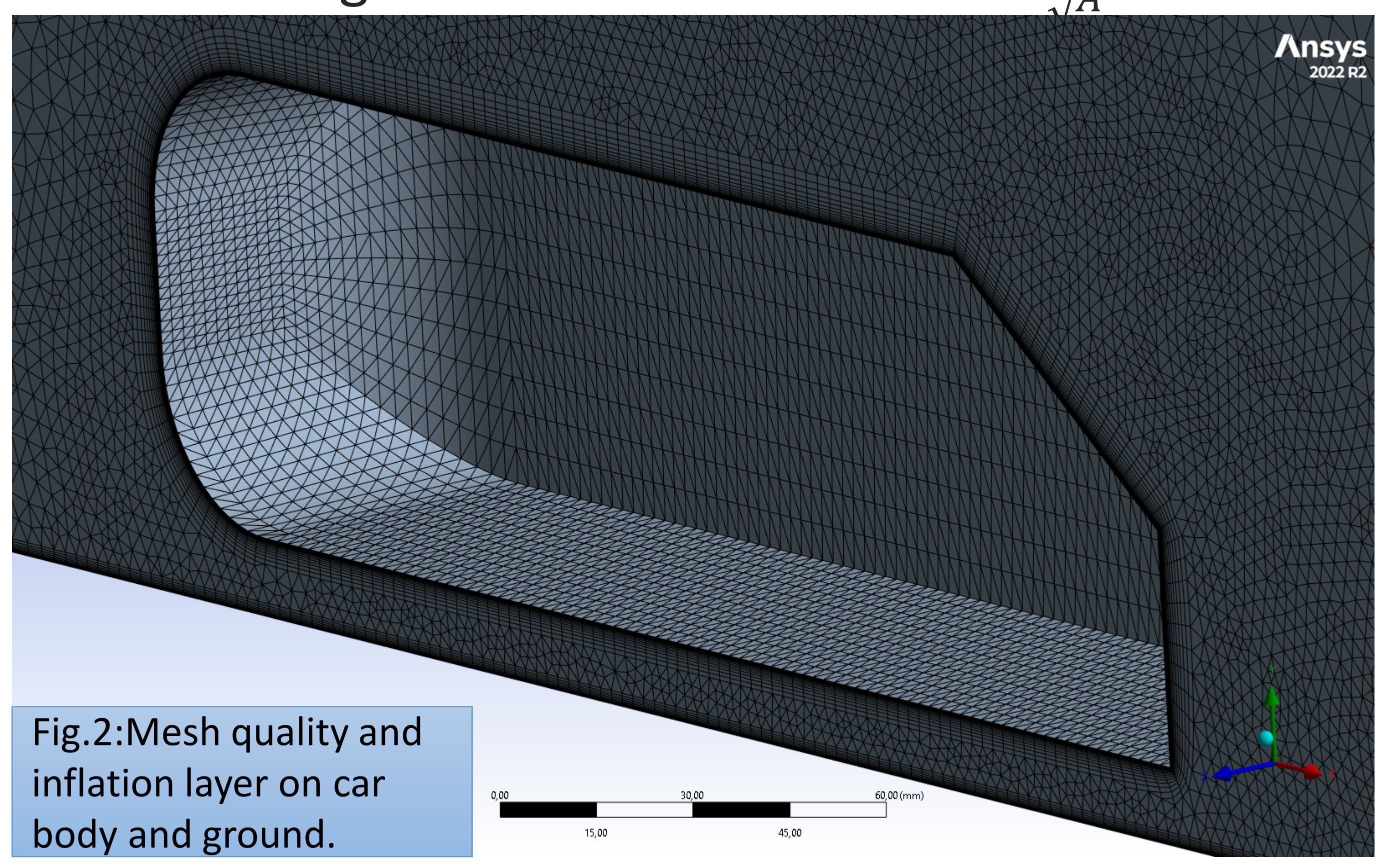


Fig.2:Mesh quality and inflation layer on car body and ground.

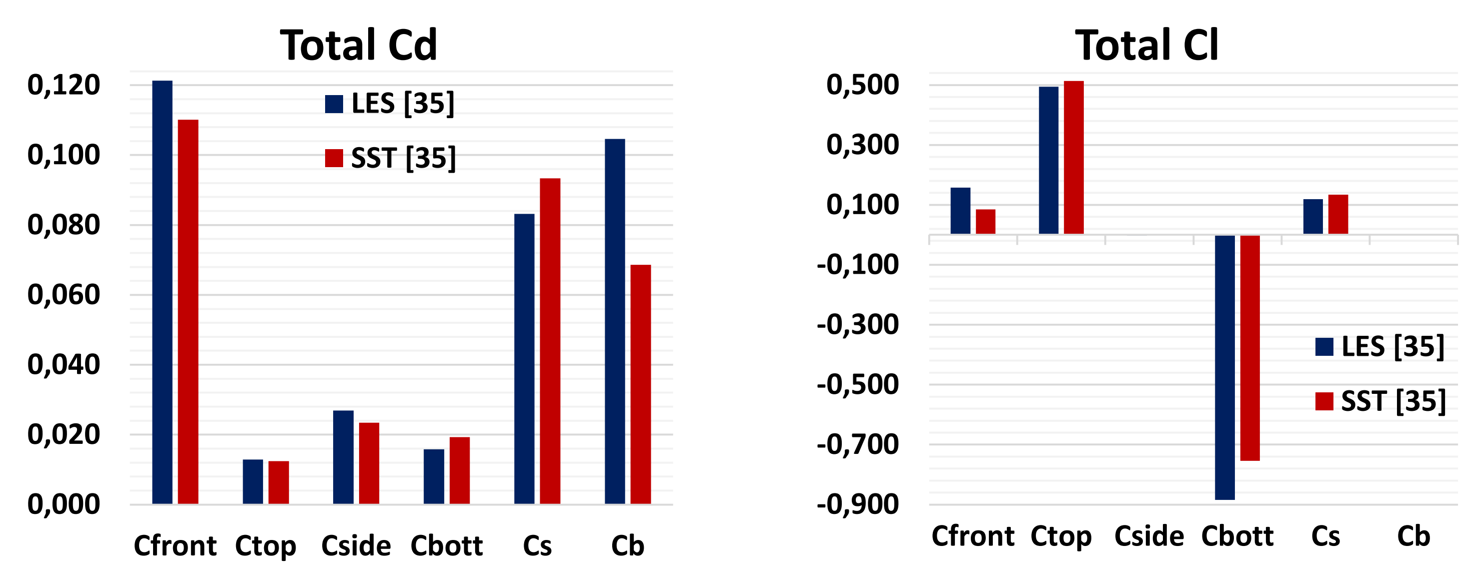


Fig.3: Drag and Lift coefficient comparison, k-ω SST and LES data.

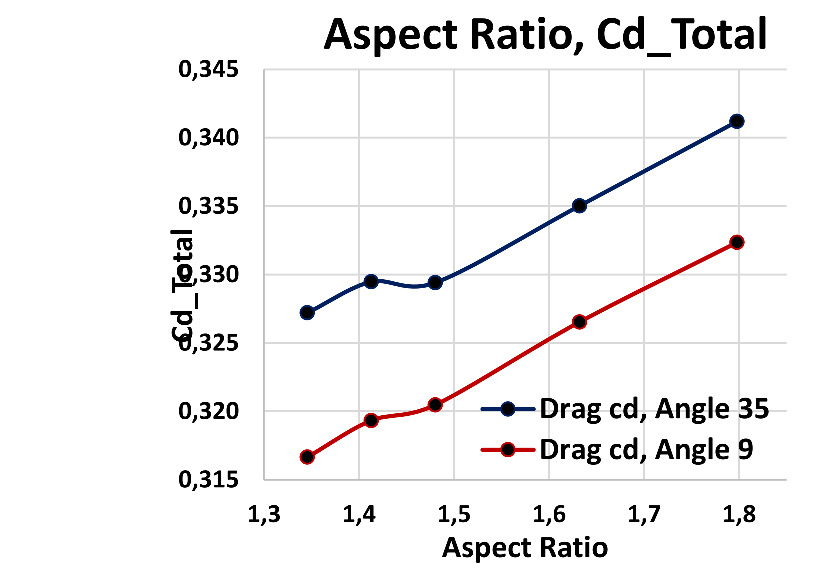


Fig.4: Aspect ratio influence on Cd_Total.

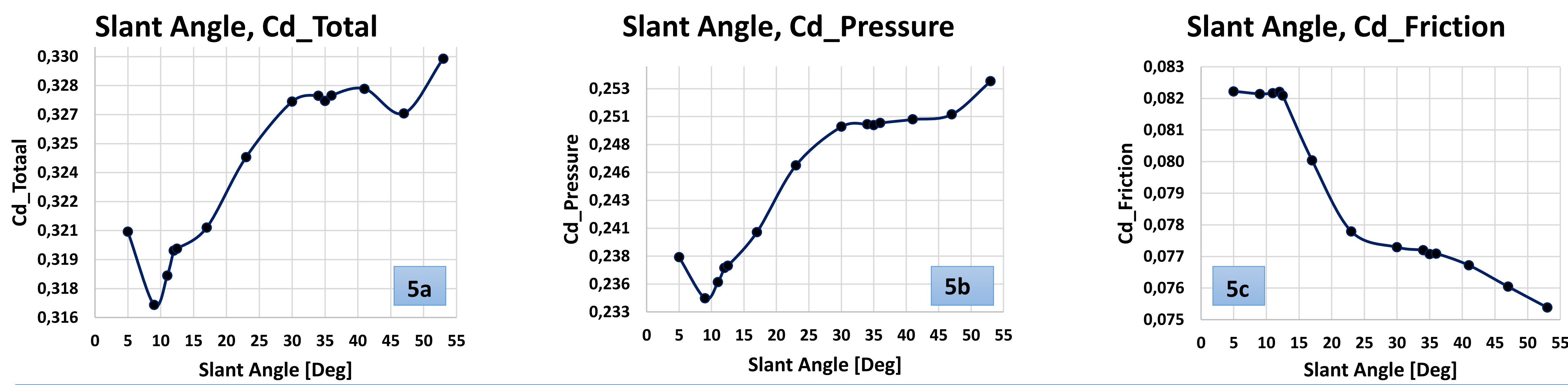


Fig.5: Drag coefficient comparison for different slant angle and component breakdown into pressure and friction drag.

Validation: Convergence criteria of 10^{-5} was achieved, and validation was performed against the LES data for total drag and lift coefficients for each surface Fig [3].

Results:

Influence of frontal aspect ratio (wider car body) with width increment [5, 10, 21.27, 33.6] % was investigated and results for Cd_Total were compared between 9° and 35° Fig[4]. The drag increase showed linear growth for both angles. For all the aspect ratio, the surface area increment was proportional, leading to consistent skin friction rise, size & strength of the wake recirculation leading to proportional pressure drag rise. Slant angle optimization estimated lowest Cd_Total for 9° slant i.e. 105.5 drag counts lesser than 35°, Fig[5a]. The average pressure drag component contribution was found to be 75.48 % and friction drag to be 24.52 %. Slant angles above 12.5° showed sudden rise in pressure Fig[5b] and fall in friction Fig[5c] drag due to 3D effect (horseshoe vortex) created by slant side longitudinal vortices and contra rotating wake re-circulations, Fig[6, 8]. The crucial observed was the detection of re-circulation bubble on the slant surface, increasing in size for [17°-30°] Leading to steep Cd_Total rise. Size decrement after critical angle [30°-40°] positioned upper wake re-circulation over the slant, aided in Cd_Total consistency and complete flow reversal over slant. Ensured wake re-circulation control over slant and back resulting in drag rise above 41° Fig[7. 8].

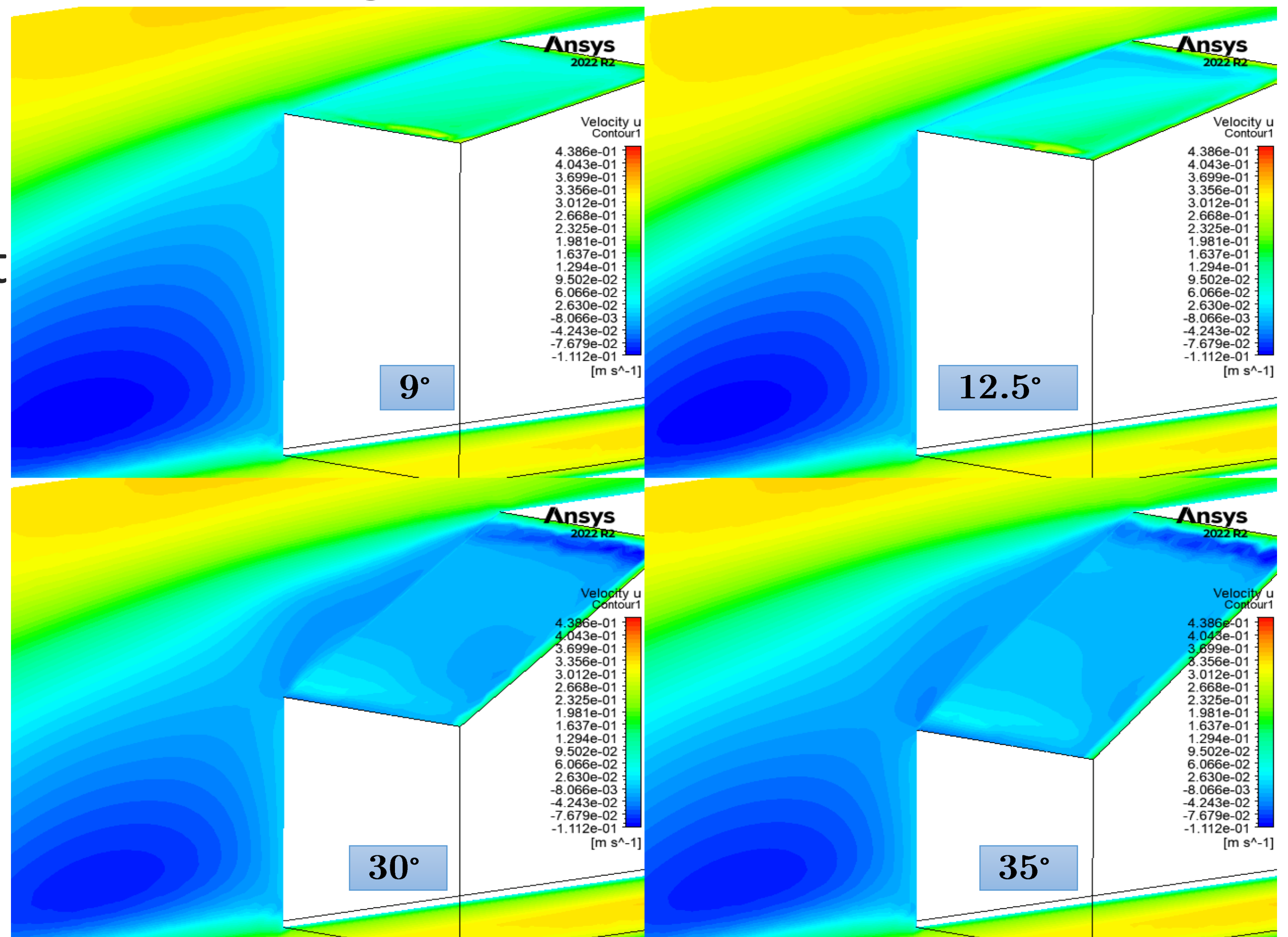


Fig.6: Slant flow reversal & wake re-circulation at crucial slant angles.

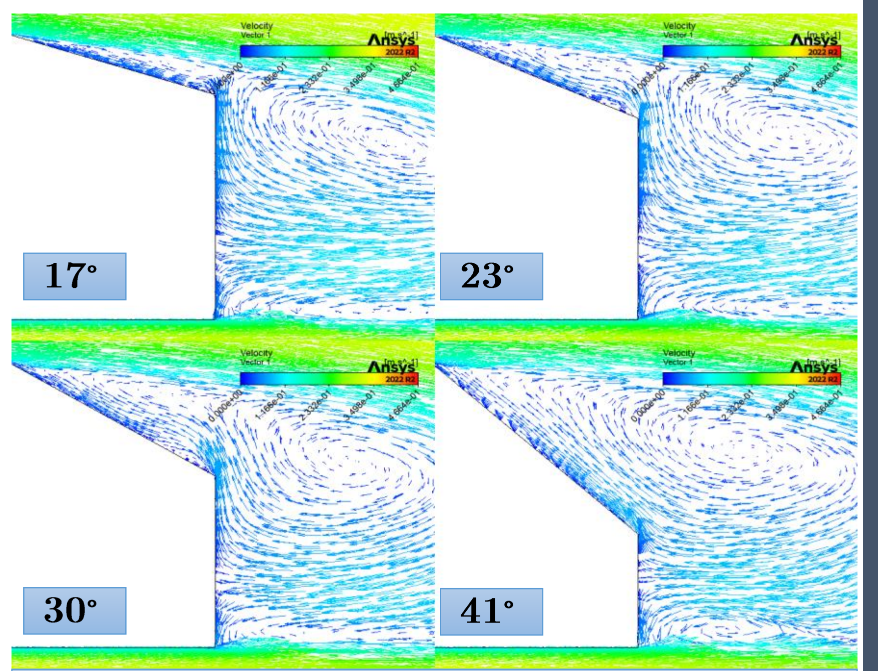


Fig.7: Side view: Re-circulation bubble on slant and contra rotating re-circulation.

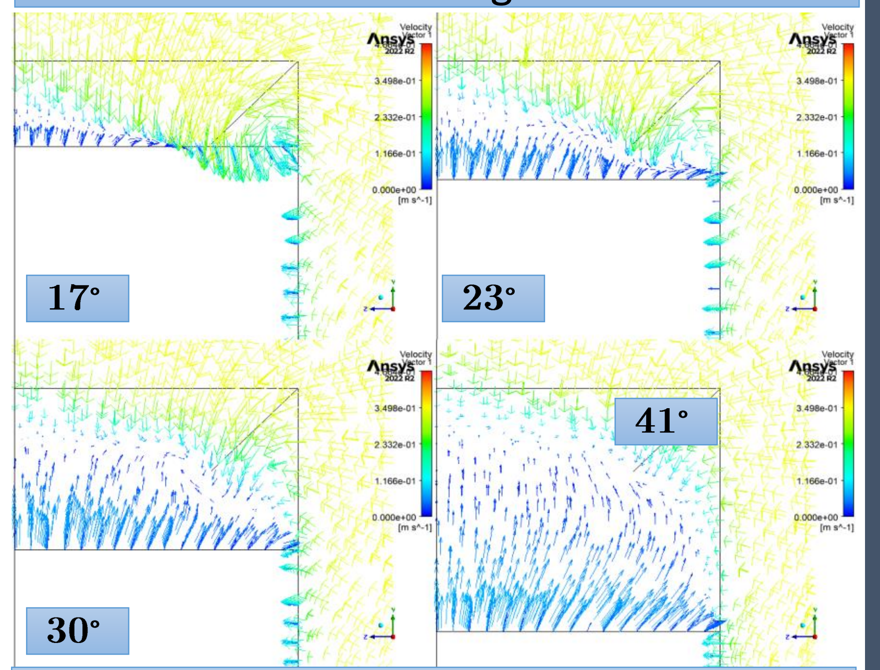


Fig.8: Back view: Slant edge longitudinal vortices & 3D effects (horseshoe vortex)

Conclusion(s)

(1) Good agreement between LES and CFD for lift and drag coefficient was achieved for the Ahmed body surfaces. **(2)** Highest reduction of 105.5 drag counts in Cd_Total observed for 9° compared to 35°. **(3)** The steep rise and fall in pressure and friction drag respectively was observed for slant angles [12.5°-30°] and flow reversal over slant for [17°-41°]. **(4)** The aspect ratio increase showed expected linear increase in the drag over the Ahmed body.

Hence, the slant angles in range (<=17°) and the low aspect ratio (<=1.5 [width/height]) are the optimum configurations to reduce drag implying low coupling in wake re-circulation and longitudinal vortices due to slant (3D effects).

Resources

[1] S. R. Ahmed, G. Ramm and G. Faltin, Some Salient Features of the Time -Averaged Ground Vehicle Wake, SAE Transactions, Vol. 93, Section 2: 840222.