Study of Lift and Drag Forces on Sedan Car by Varying Spoiler Angles

Basa Nagaraju[1*], Rajesh Ghosh[2], M Pavan Teja[3]

[1]Asistant Professor, Mechanical Engineering Department, ANITS, Visakhapatnam, India

*Corresponding Author E-mail: bnagaraju.me@anits.edu.in

[2]Associate Professor, Mechanical Engineering Department, ANITS, Visakhapatnam, India

E-mail: rajesh_ghosh@yahoo.com

[3]Student, Mechanical Engineering Department, ANITS, Visakhapatnam, India

E-mail: pavantejamadugula@gmail.com

Abstract: Drag force is one of the main constraints to reduce the fuel efficiency. Increasing lift force results in decreased stability of vehicle handling. Ongoing research of automobiles is focused on reducing the drag and lift forces which will increase the fuel economy and the stability of the vehicle. This can be achieved by proper streamlining of vehicle body or by attaching a rear end spoiler. In the present study, the drag and lift forces of a sedan type car without spoiler and spoiler with different inclinations are studied by using fluent flow solver in ANSYS workbench software. It is observed that, the lift and drag forces on car body are reduced by attaching a spoiler. It is further observed that the lift and drag forces are decreasing with increased angle of spoiler in the downward direction whereas increases with increased angle in the upward direction.

Keywords: CFD, Spoiler, Lift force, Drag Force, Sedan Car

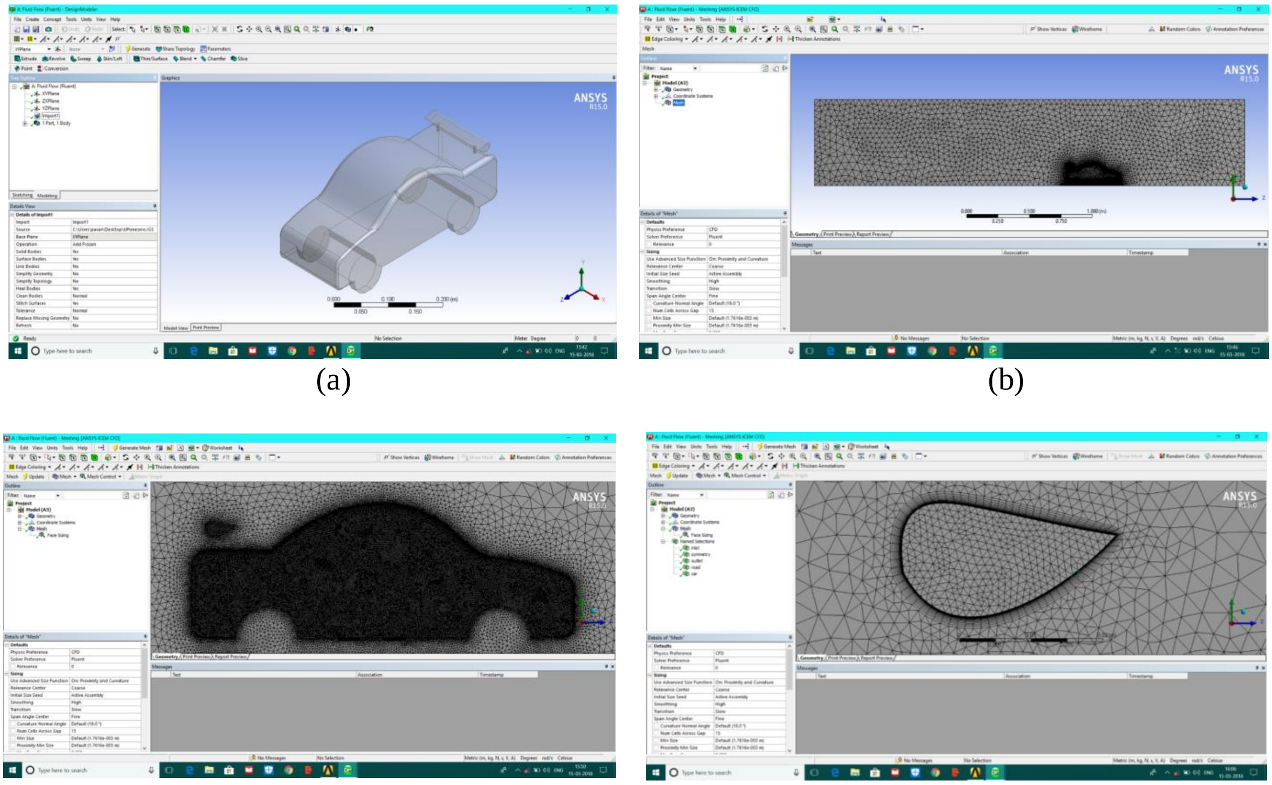
I. INTRODUCTION

Due to ever increasing oil prices, automobile industries are working towards maximizing fuel efficiency. Among other parameters, aerodynamics of automobile is an important part of automobile design. The external flow has a significant effect on the aerodynamic performance of an automobile. Much research is focussed on improving the fuel efficiency by controlling the external flow to reduce the aerodynamic drag. At high speeds, the aerodynamic characteristics, and drag around the rear significantly affect the total CD of an automobile. Therefore, the external flow pattern is controlled by modifying the outer shape of an automobile to improve the aerodynamics performance. Song et al [4] used Artificial Neutral Network (ANN) and proposed an aerodynamically optimized outer shape of a sedan by using D-optimal methodology. Their focus is mainly on modifying the rear body shapes of the sedan. Sapnaras and Dimitrou [3] analyzed the underbody pressure distribution of series-vehicle including wheel rim and tyre. Albukerk et al [1] analyzed unsteady flow dynamics of a formula type race car in turning condition by using power flow which provides better unsteady flow solution compared to normal CFD solvers. Aider et al [2] conducted experiments on 3D bluff body by controlling the flow through moving flaps fixed around the rear end. Experiments were further continued at different pairs of flaps at different angles and showed most efficient configuration for flaps is along the side edges of rear slant. Wassen et al [6] work focused on an active flow control approach to reduce drag of a generic square-back vehicle and suggested a blowing angle of 45^0 was most effective. Song et al [5] used bionic non-smooth surfaces to reduce drag force. They showed by CFD simulation results that properly designed non-smooth surfaces can reduce drag compared to smooth surfaces.

Based on the literature review, it is understood that the drag force causes increase in fuel consumption and is required to be reduced. Drag force is reduced by proper stream lining of car body or by attaching a spoiler. By attaching a spoiler, lift force can be reduced at high speeds along with drag force. Therefore, effect of spoiler at different angles on lift and drag forces can be studied and can suggest a suitable angle of spoiler which will give least drag and lift forces.

II. SIMULATION PROCEDURE

A sedan type car is selected for the study purpose. The car geometry is drawn in solid works and fluid flow analysis is carried out using fluent software in ANSYS work bench. Proper care is taken to capture the flow parameters at the rear of the car by giving inflation layers near the spoiler as shown in fig 1. A steady state incompressible solution of the Navier-Stokes equations was obtained by implementing turbulent modelling with standard wall functions and second order upwind discretization scheme. The flow field data was generated in the post processing and contours of static pressure and velocity vectors were obtained and analyzed. The values of drag and lift coefficient were also found out for different input velocities.



(a) (b) (c) (d)

Figure 1. (a) Geometry of car, (b) Meshing of wind tunnel and car body, (c) Face sizing applied to car body, (d) Mesh showing inflation layer around the car body

III. RESULTS AND DISCUSSION

Analysis is carried out on sedan type (Honda City) car without rear end spoiler and with rear end spoiler at different angles at different car velocities. Two different velocities of 60 kmph and 160 kmph are selected for the study purpose. The pressure, velocity distributions on the car body along with lift and drag coefficients are found by simulation. The obtained results are discussed hereunder.

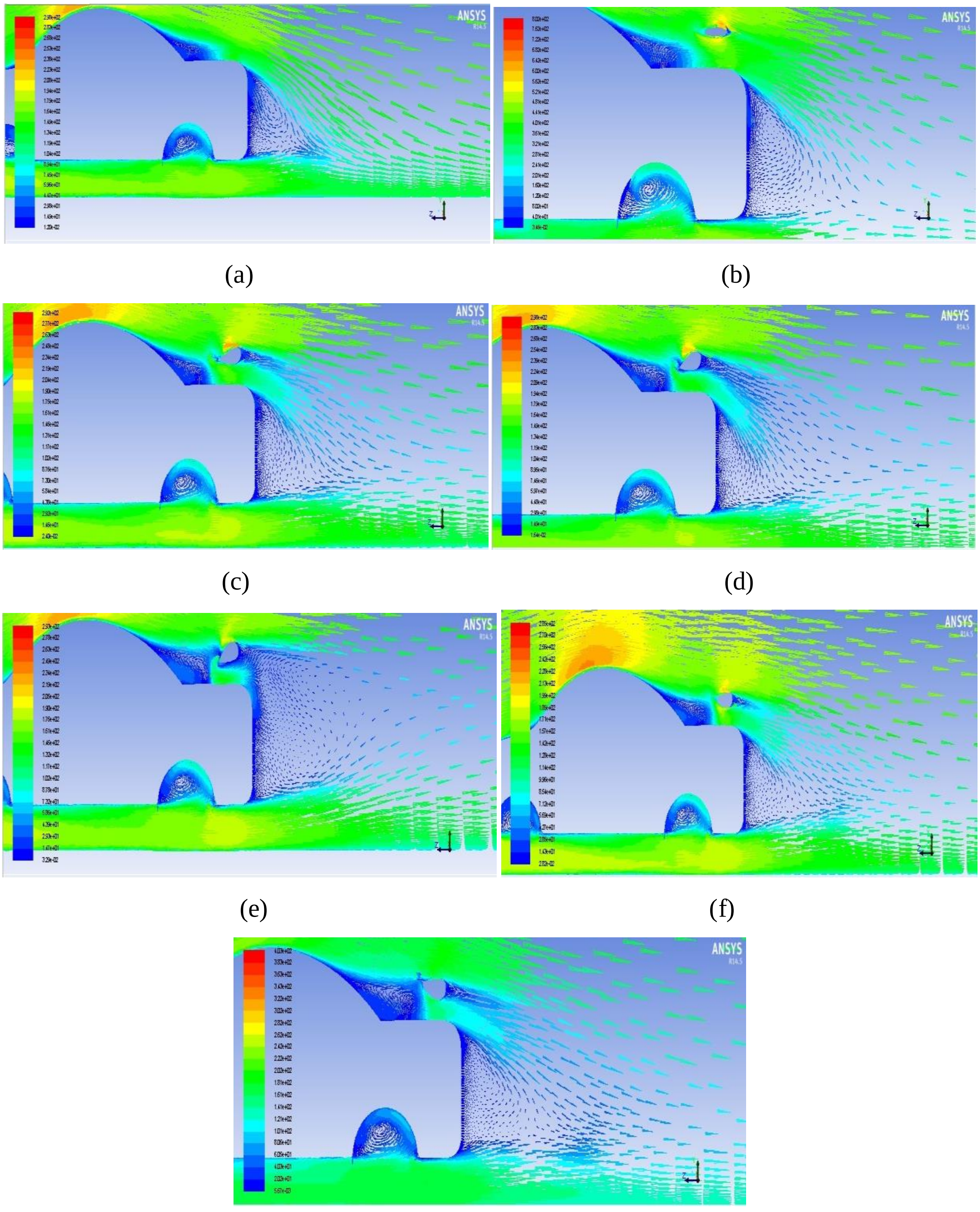
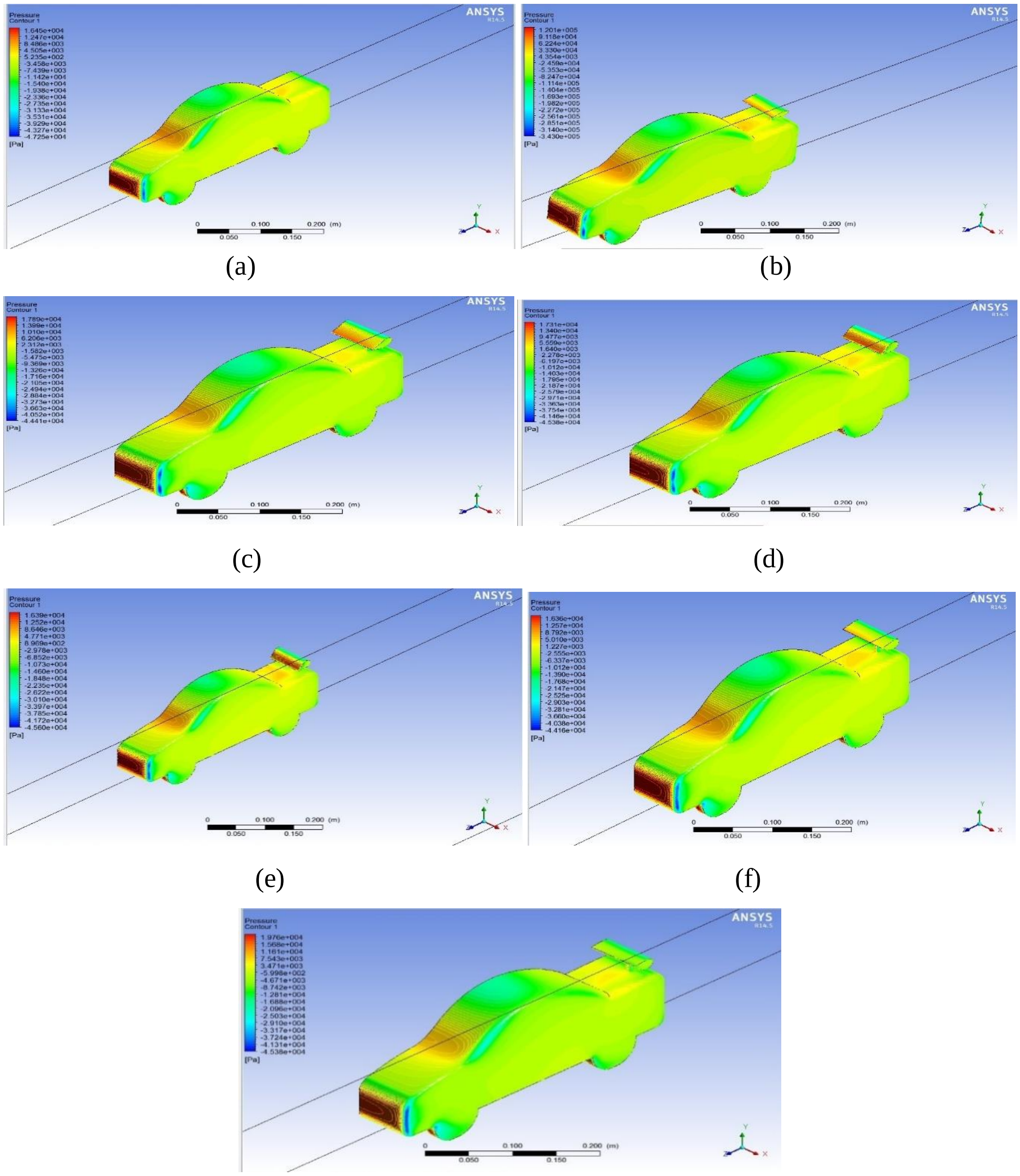


Figure 2. Recirculation zones at the rear end of car at 60 kmph (a) without spoiler (b) spoiler at 0 degrees (c) spoiler at 10 degrees downwards (d) spoiler with 20 degrees downwards (e) spoiler with 30 degrees downwards (f) spoiler with 10 degrees upwards (g) spoiler with 20 degrees upwards



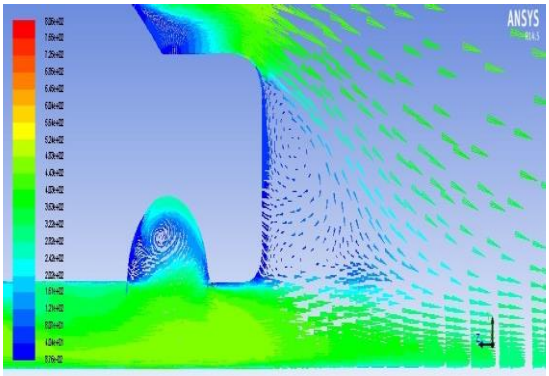
(g)

Figure 3. pressure contours over the car at 60 kmph with (a) without spoiler, (b) zero-degree spoiler, (c) ten-degree inclination spoiler downwards, (d) twenty-degree inclination spoiler downwards, (e) thirty-degree inclination spoiler downwards, (f) ten-degree inclination spoiler upwards (g) twenty degree inclination spoiler upwards.

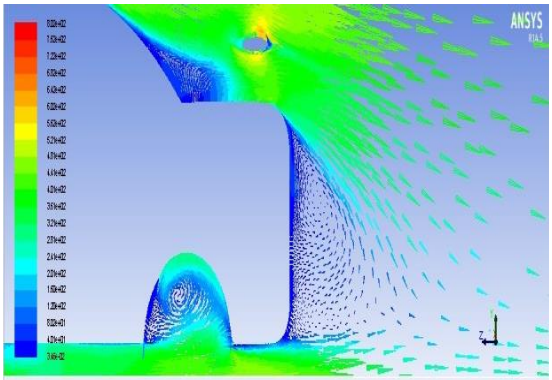
The results obtained at car velocity 60 kmph are shown in fig. 2 and fig. 3. Fig. 2(a) to 2(e) shows the recirculation of air at the rear end without spoiler and with spoiler inclining downwards. It is observed that the flow separation is reduced from fig. 2(a) to 2(e) which results in reduced drag as the inclination of spoiler increases downwards. From fig. 2(e), it is observed that the flow is attached with the car body completely which results in lower drag compared to others. Fig. 2(f) & 2(g) shows the recirculation of air with spoiler inclining upwards. It is observed that, as the inclination of spoiler increases upwards flow separation is increased which results in increased drag.

Fig. 3(a) to 3(e) shows the pressure distribution over car body with spoiler angles increasing in downward direction. It is observed that the pressure on upper side of spoiler is increasing results in reducing the lift of the car. From fig. 3(e), it is observed that the very high pressure on the upper side of spoiler compared to others gives reduction of lift by 96%. Fig. 3(f) & 3(g) represents the pressure distribution over car with spoiler inclining upwards at 10 and 20 degrees respectively. It is observed that the pressure on upper side of spoiler is lower and is decreased as inclination increases which results in increased lift of the car.

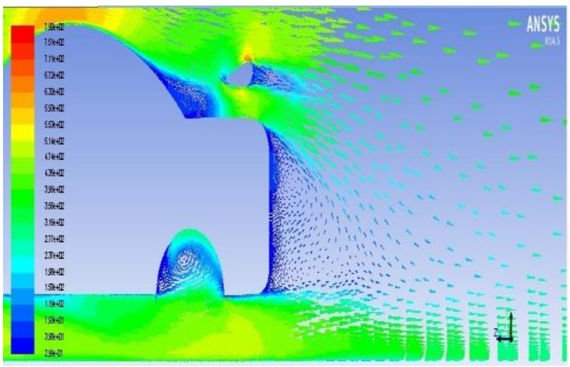
The results obtained at car velocity 160 kmph are shown in fig. 4 & 5. The results obtained are qualitatively like the results obtained at car velocity of 60 kmph but differ quantitatively. Table 4.1 compares the drag and lift coefficients of car at velocities 60 kmph and 160 kmph. The variation of drag and lift coefficients of car at velocities 60 and 160 kmph at different spoiler conditions are shown in figure 6 & 7 respectively. It is observed that, the values of lift and drag coefficients are less at lower velocities as expected. Figure 6 & 7 shows the reduction of lift and drag coefficients of car with spoiler. Therefore, the spoiler addition is always suggestible irrespective of velocity of car. Further it is observed that, by increasing the spoiler angle upwards, the lift and drag coefficients shows increasing trend whereas by increasing angle downwards, the lift and drag coefficients shows reducing trend.



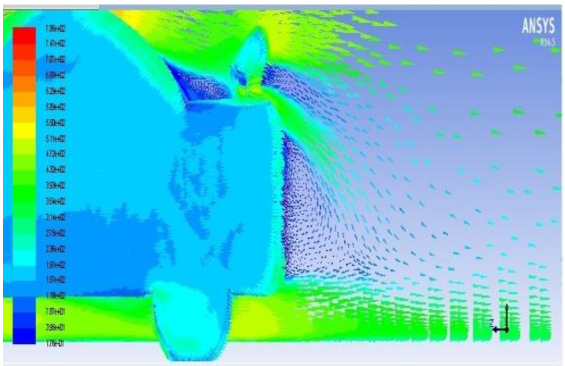
(a)



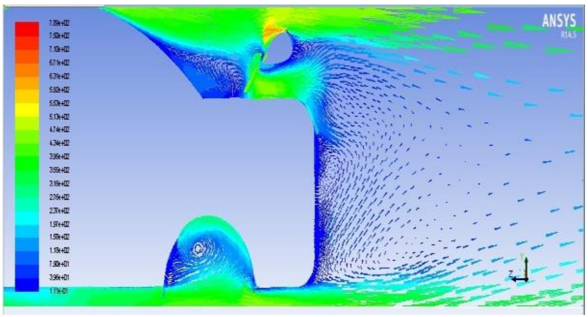
(b)



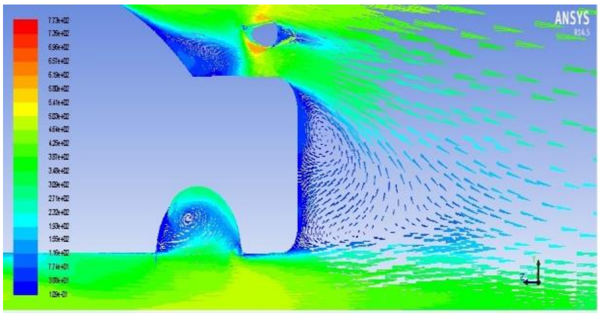
(c)



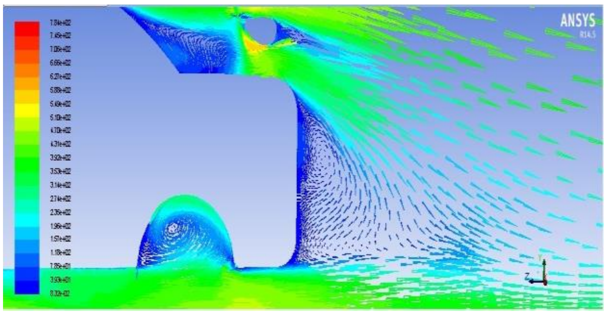
(d)



(e)

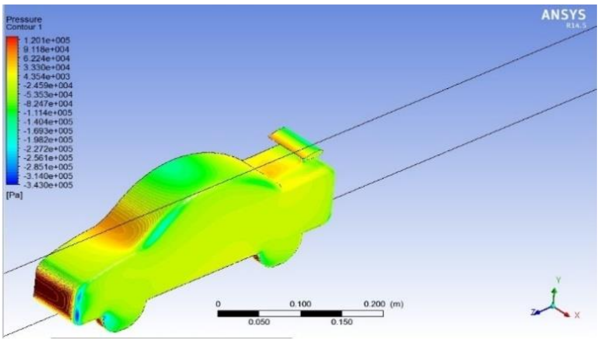


(f)

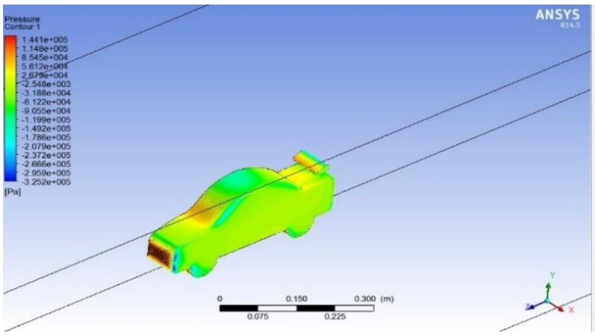


(g)

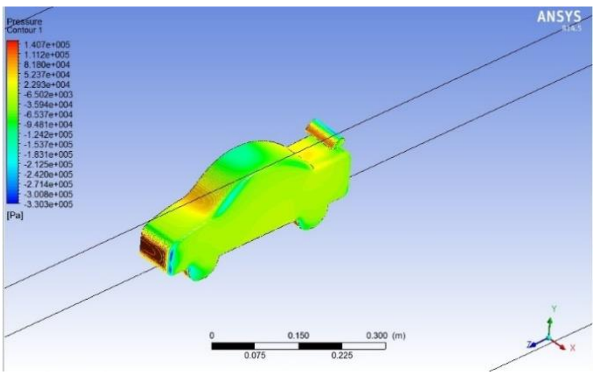
Figure 4. Recirculation zones at the rear end of car at 160 kmph (a) without spoiler (b) spoiler at 0 degrees (c) spoiler at 10 degrees downwards (d) spoiler with 20 degrees downwards (e) spoiler with 30 degrees downwards (f) spoiler with 10 degrees upwards (g) spoiler with 20 degrees upwards



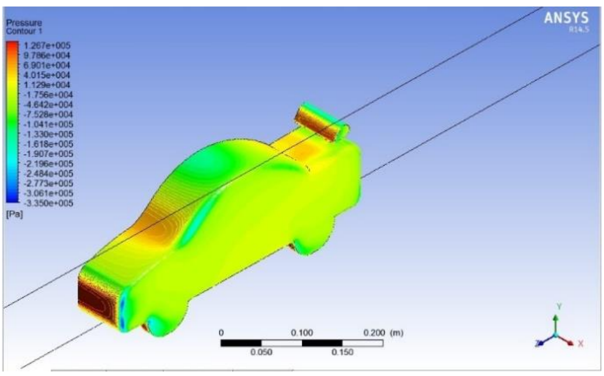
(a)



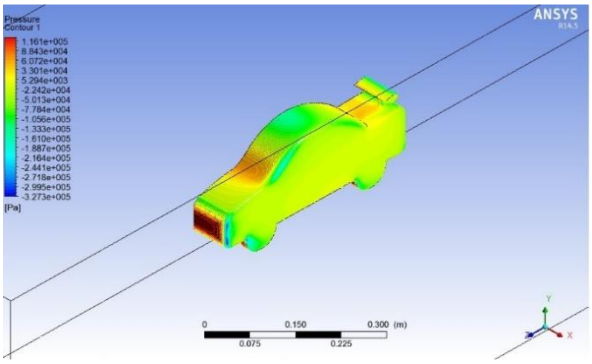
(b)



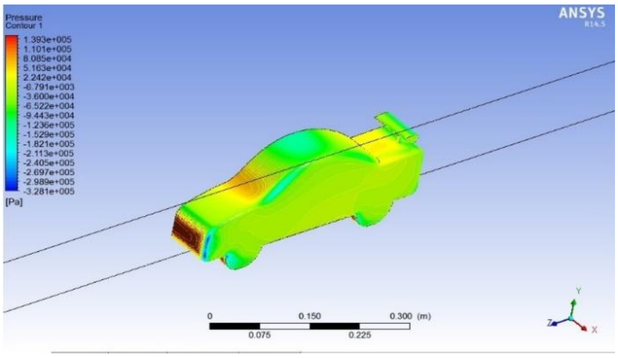
(c)



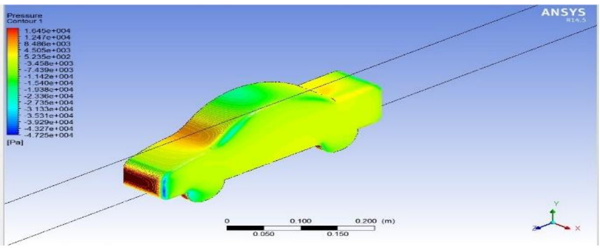
(d)



(e)



(f)



(g)

Figure 5. pressure contours over the car at 160 kmph with (a) zero-degree spoiler (b) ten-degree inclination spoiler downwards (c) twenty-degree inclination spoiler downwards (d) thirty-degree inclination spoiler downwards (e) ten degree inclination spoiler upwards (f) twenty degree inclination spoiler upwards (g) without spoiler

Table 1. Comparison of drag and lift coefficients without and with spoiler at different inclinations and at car velocities of 60 kmph and 160 kmph.

Spoiler Condition / Velocity of car	60 kmph		160 kmph	
	Drag coeff. (C_D)	Lift coeff. (C_L)	Drag coeff. (C_D)	Lift coeff. (C_L)
without spoiler	0.252960	0.072735	0.251190	0.068970
Spoiler with zero inclination	0.238320	0.028473	0.247070	0.040476
Spoiler with 10° inclination upwards	0.238250	0.027836	0.240420	0.028241
Spoiler with 20° inclination upwards	0.238620	0.037613	0.241750	0.049448
Spoiler with 10° inclination downwards	0.238930	0.021108	0.242640	0.018175
Spoiler with 20° inclination downwards	0.237990	0.024149	0.241750	0.021224
Spoiler with 30 ° inclination downwards	0.237850	0.002232	0.239910	0.002540

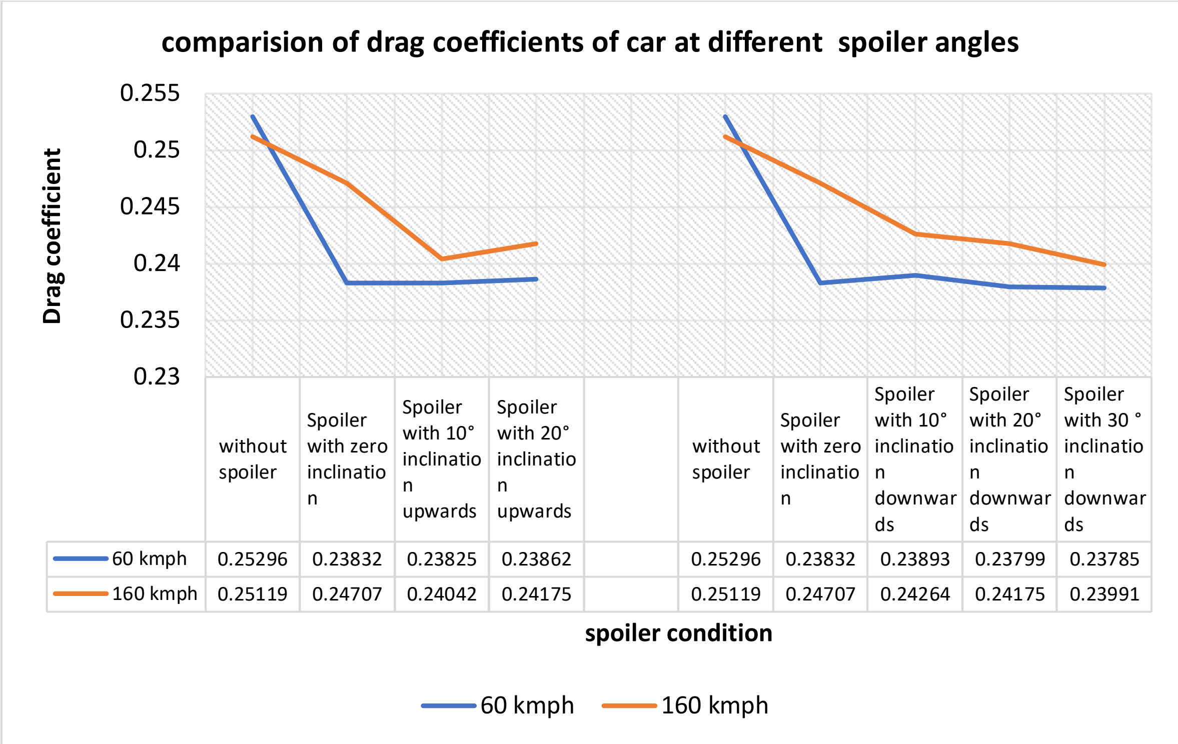


Figure. 6. comparison of drag coefficient of car at different velocities with varying spoiler angles.

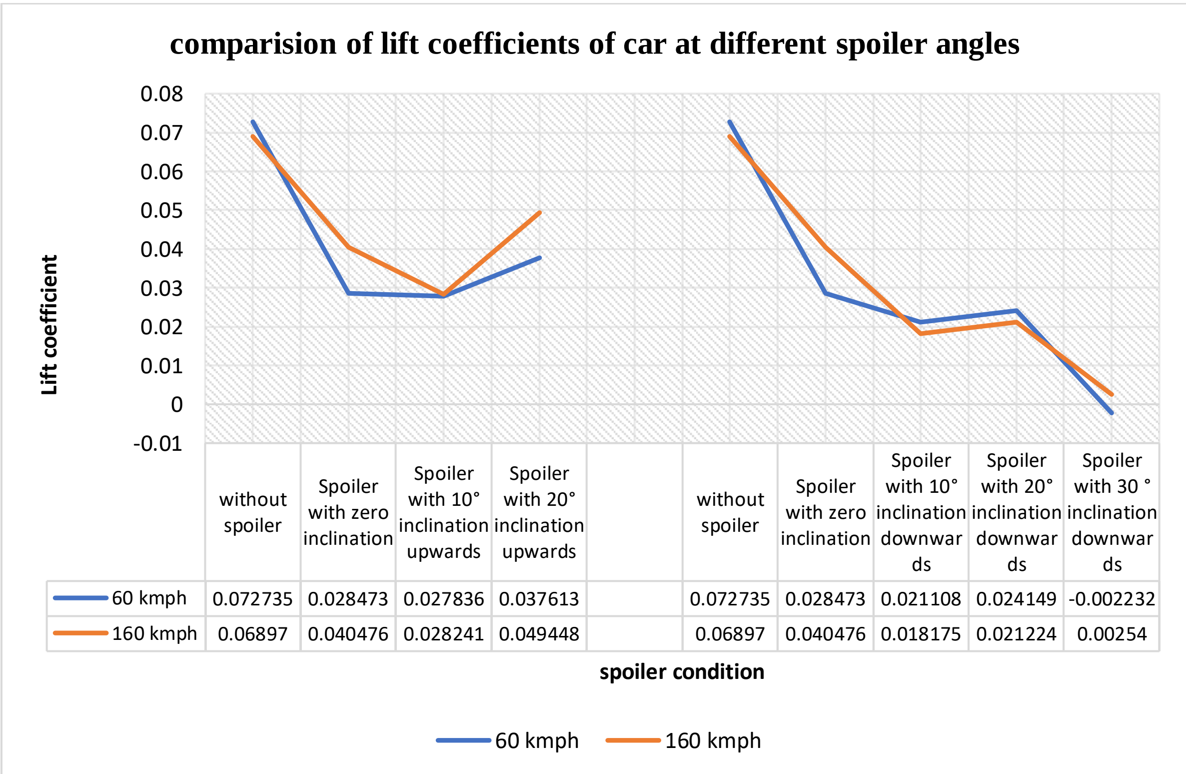


Figure. 7. comparison of lift coefficient of car at different velocities with varying spoiler angles.

The drag coefficient reduces by 5.97% and lift coefficient by 96.3% with the attachment of spoiler at inclination of 30 degrees downwards at a velocity of 60 kmph. The drag coefficient reduces by 4.5% and lift coefficient by 103.06% with the attachment of spoiler at inclination of 30 degrees downwards at a velocity of 160 kmph.

At a car velocity of 60 kmph, the lift coefficient of car with spoiler inclining downwards at an angle 30 degrees is -0.002322. It shows that the car will not lift off from ground and it is always pushed towards the ground maintaining better stability.

IV. CONCLUSIONS

Lift and drag forces are lesser for a vehicle fitted with spoiler. The spoiler inclining downwards reduces the lift and drag forces compared to inclining upwards. The drag coefficient reduces by 5.97% and lift coefficient by 96.3% with the attachment of spoiler at inclination of 30 degrees downwards at a velocity of 60 kmph. The drag coefficient reduces by 4.5% and lift coefficient by 103.06% with the attachment of spoiler at inclination of 30 degrees downwards at a velocity of 160 kmph. Therefore, by attaching a spoiler with downward inclination reduces drag and lift drastically and gives better fuel economy and stability. It is found that each velocity has it respective spoiler angle for optimum performance of the vehicle. Hence a sensor-based spoiler may be installed that can adjust automatically according to varying velocities to give optimum performance of the vehicle.

Conflict of interest: The authors declare that they have no conflict of interest.

Ethical statement: The authors declare that they have followed ethical responsibilities

REFERENCES

[1] RENCAlbukrek, C., Doddegowda, P., Ivaldi, A., Amodeo, J., & Bardoscia, E. (2006). Unsteady Flow Analysis of a Formula Type Open Wheel Race Car in Cornering (SAE Technical Paper No. 2006- 01–3661). Warrendale, PA: SAE Technical Paper. https://doi.org/10.4271/2006-01-3661

[2] Beaudoin, J.-F., & Aider, J.-L. (2008). Drag and lift reduction of a 3D bluff body using flaps. Experiments in Fluids, 44(4), 491. https://doi.org/10.1007/s00348-007-0392-1

[3] Sapnaras, D., & Dimitriou, I. (2008). Experimental Analysis of the Underbody Pressure Distribution of a Series Vehicle on the Road and in the Wind Tunnel (SAE Technical Paper No. 2008- 01–0802). Warrendale, PA: SAE International. https://doi.org/10.4271/2008-01-0802

[4] Song, K. S., Kang, S. O., Jun, S. O., Park, H. I., Kee, J. D., Kim, K. H., & Lee, D. H. (2012). Aerodynamic design optimization of rear body shapes of a sedan for drag reduction. International Journal of Automotive Technology, 13(6), 905–914. https://doi.org/10.1007/s12239-012-0091-7

[5] Song, X., Zhang, G., Wang, Y., & Hu, S. (2011). Use of bionic inspired surfaces for aerodynamic drag reduction on motor vehicle body panels. Journal of Zhejiang University-SCIENCE A, 12(7), 543–551. https://doi.org/10.1631/jzus.A1000505

[6] Wassen, E., Eichinger, S., & Thiele, F. (2010). Simulation of Active Drag Reduction for a Square-Back Vehicle. In Active Flow Control II (pp. 241–255). Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-11735-0_16

This volume is dedicated to Late Sh. Ram Singh Phanden, father of Dr. Rakesh Kumar Phanden.

