Vehicle Handling Analysis with Aerodynamic Interactions

Group - 6

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Aerodynamic Characteristics affect the following:

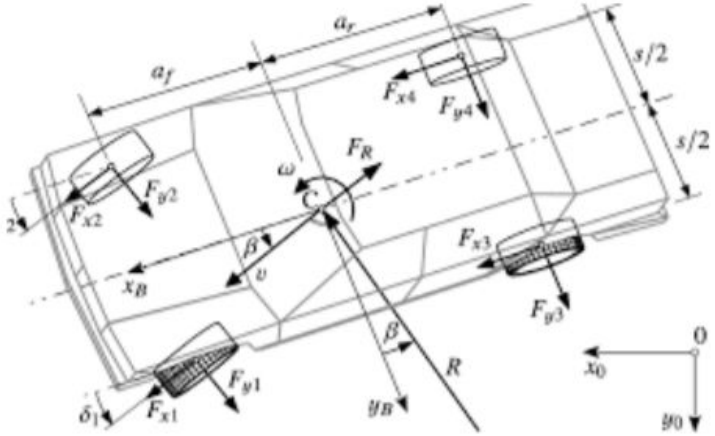
- Power
- Economy
- Handling stability
- Comfort

Aerodynamic Characteristics result a change in:

- Velocity
- Pressure
- Lift
- Resistance

Critical Speed

Critical speed is the speed above which the car loses its lateral stability while compensating a corner.



$$N_1 = \frac{mg - L}{2} - \frac{mv^2 h}{sr}$$

$$N_2 = \frac{mg - L}{2} + \frac{mv^2 h}{sr}$$

At Critical speed,

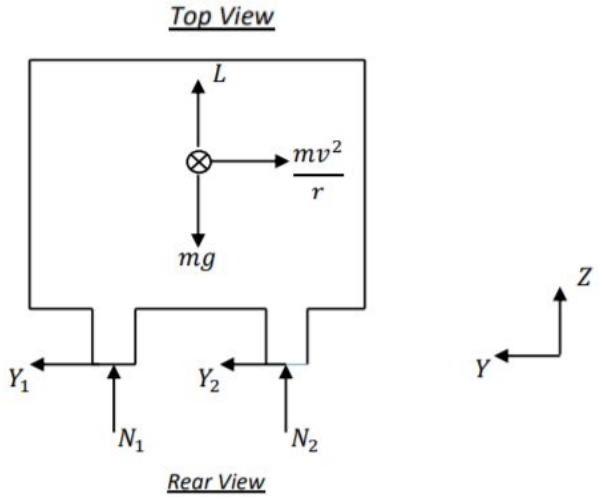
$$N_1 = \frac{mg - L}{2} - \frac{mv^2 h}{sr} = 0$$

But, aerodynamic lift is given by

$$L = \frac{1}{2}\rho A v^2 C_L$$

Thus we get,

$$v_{crit}(r) = \sqrt{\frac{mg}{2} * \frac{1}{\left(\frac{\rho A C_L}{4}\right) + \frac{mh}{sr}}}$$



Braking and Stopping Distance

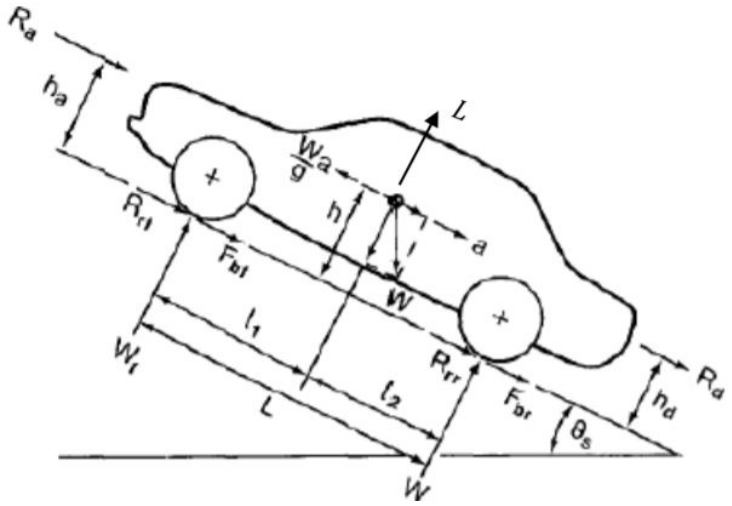
At low speeds,

$$\int_{V_i}^{V_f} V.dV = \int_0^{SD} -\frac{F_{xt}}{M}\, dX$$

$$\therefore SD = \frac{M}{2F_{xt}}(V_i^2 - V_f^2)$$

When V_f = 0

$$\boxed{SD = \frac{MV_i^2}{2F_{xt}}}$$



If the aerodynamic forces are taken into consideration, the resulting equation for stopping distance is a bit complicated. It is given by,

$$\int_{V_i}^{0} V.dV = \int_0^{SD} -\frac{F_b + CV^2}{M}\, dX$$

$$\boxed{SD = \frac{M}{2C}.\ln\left[\frac{F_b + CV_i^2}{F_b}\right]}$$

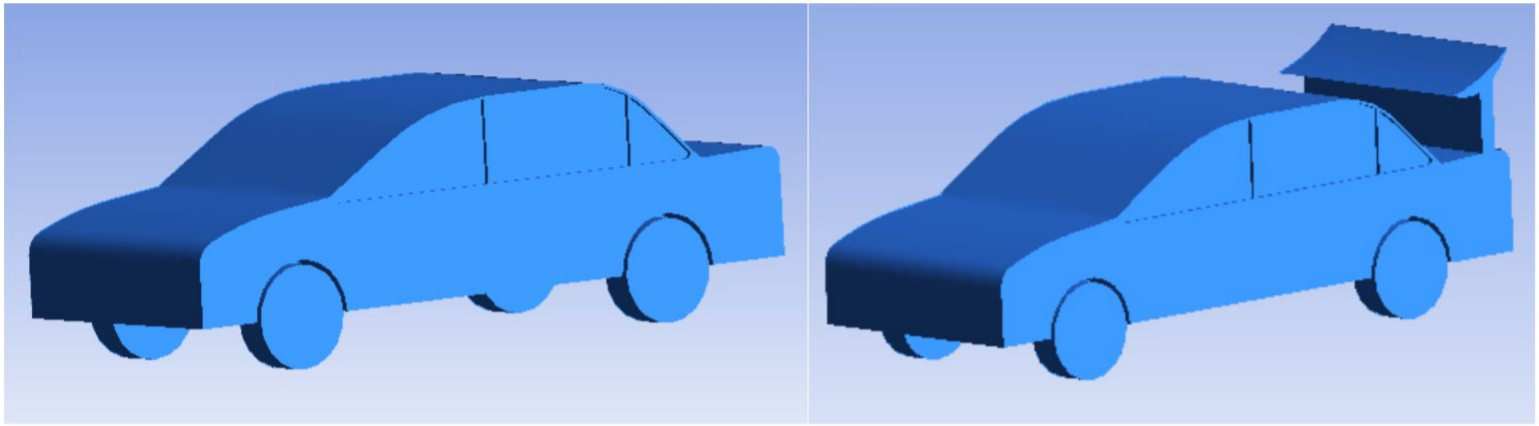
Where, Fb is the total braking force in front and rear and $C = \frac{1}{2}\rho A C_d$ (here Cd is the coefficient of drag).

Aerodynamic Simulation

Tools used and boundary conditions:

- ANSYS Fluent Solver (Fluid Medium - Air @ 25^0 C)
- SOLIDWORKS 2018 for CAD

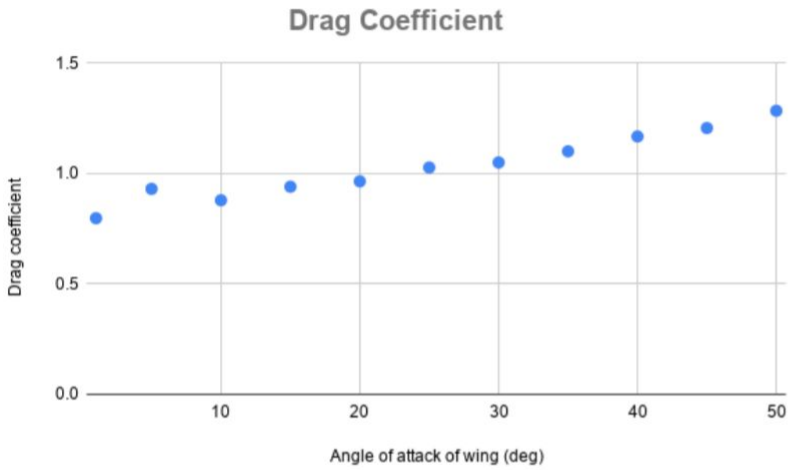
CAD Model of the car



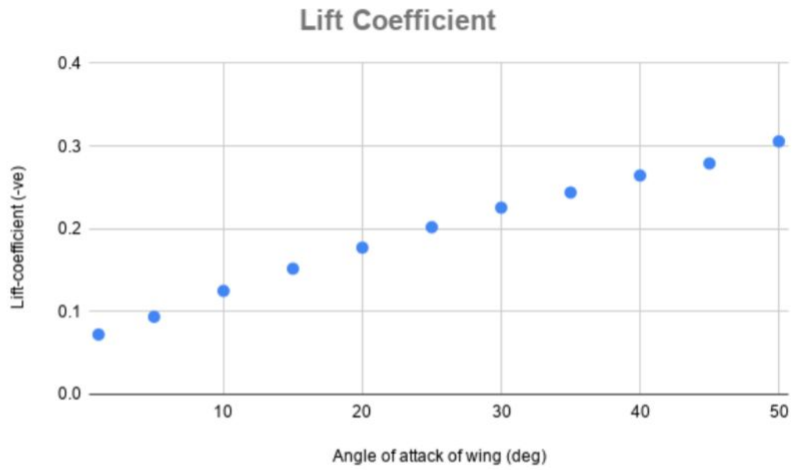
Without rear-wing

With rear-wing

The simulation was performed for the various angles of attack of the rear and the coefficient of drag and coefficient of lift (down-force here) was plotted as follows.

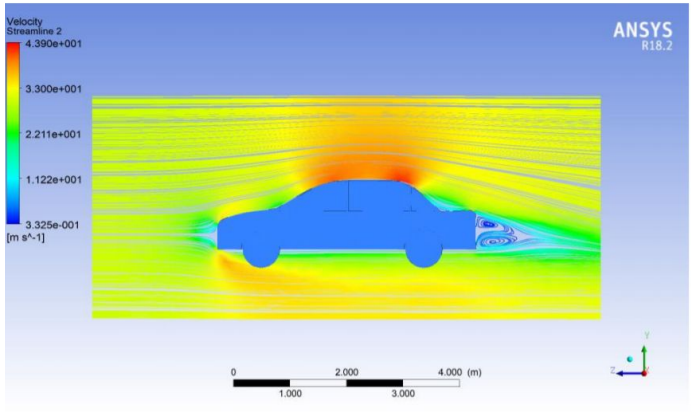


Plot of Drag Coefficient vs *Angle of attack*

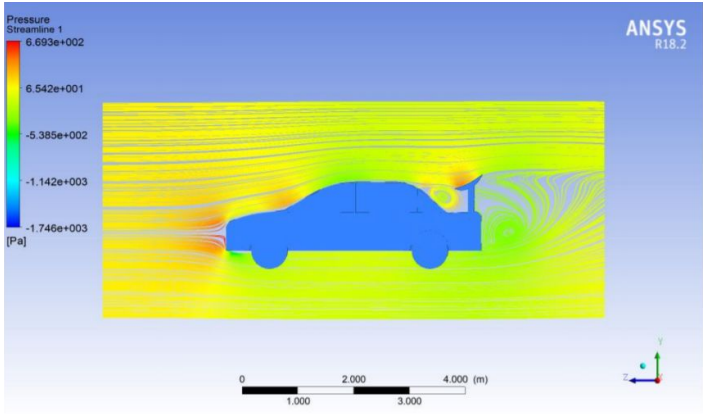


Plot of Lift Coefficient vs *Angle of attack*

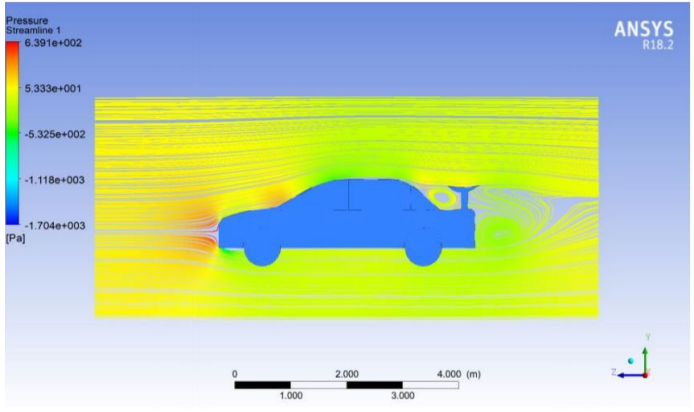
Effect of wing on lift and drag forces:



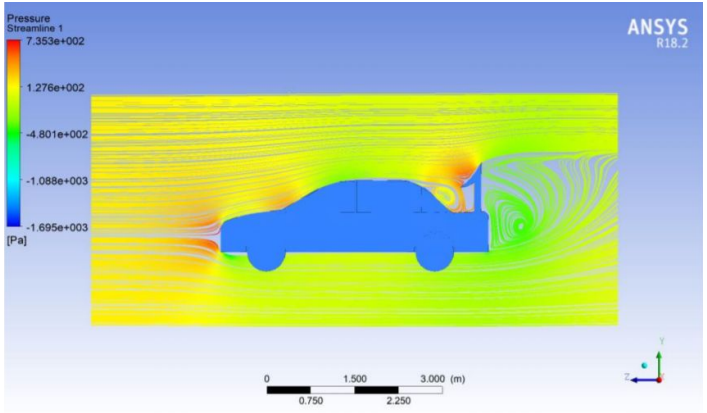
without rear-wing



with rear-wing

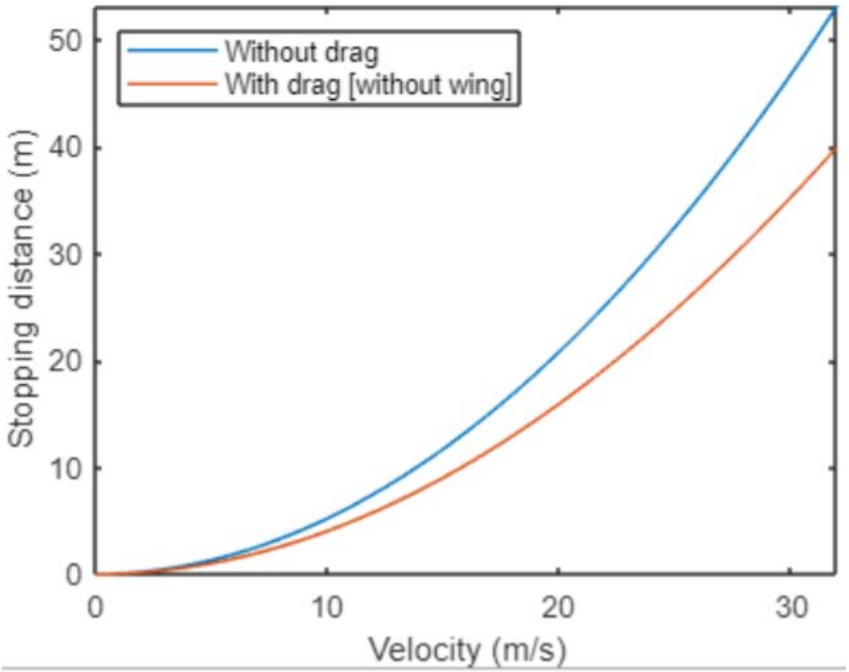


wing at lowest angle of attack

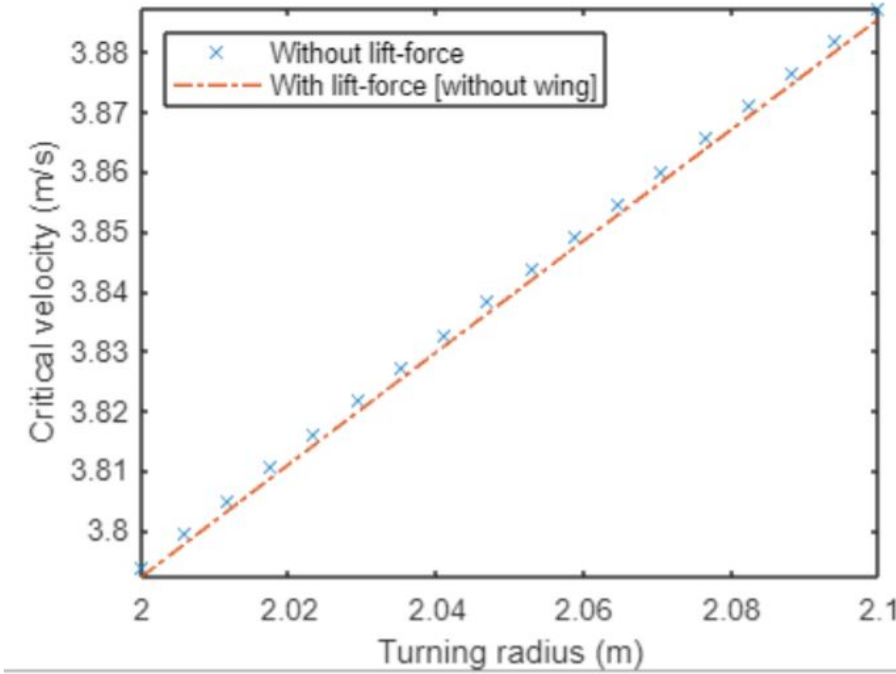


wing at maximum angle of attack

Effect of Aerodynamic Interaction on Vehicle Handling



Plot of Stopping distance vs Velocity of the vehicle



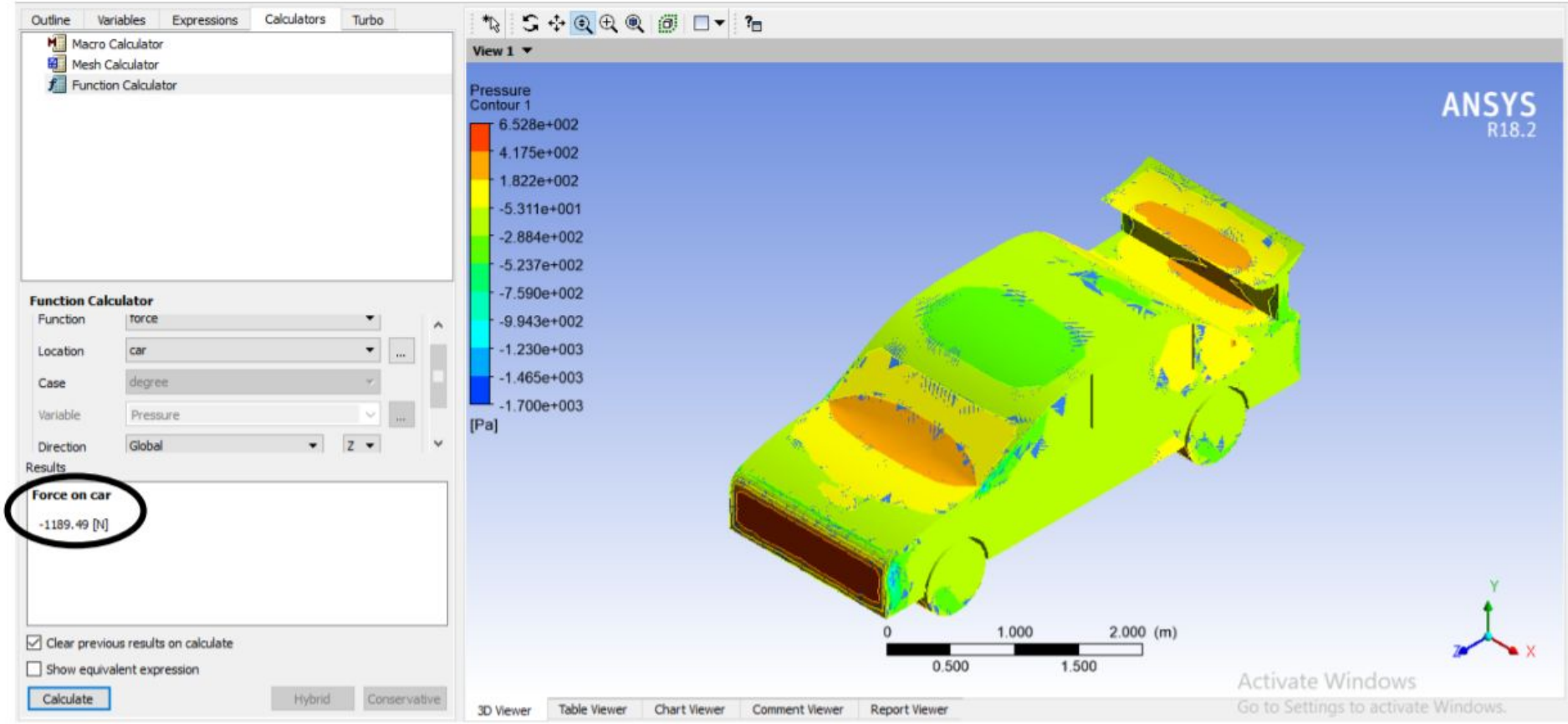
Plot of Critical velocity vs Turning radius of the vehicle

Use of Rear Wing

The rear wing can be used to increase the downforce as well as the drag acting upon the car. The analysis was performed for the wing over the vehicle for varying angles of attack betweer 0º - 50º .

Angel of attack (º)	Drag force (N)	Downforce (N)
1	989.801	320.428
5	1154.600	415.194
10	1090.940	553.096
15	1189.490	670.275
20	1263.500	779.892
25	1389.560	885.159
30	1463.950	983.571
35	1577.430	1061.850
40	1716.920	1151.250
45	1814.650	1214.950
50	1972.780	1330.640

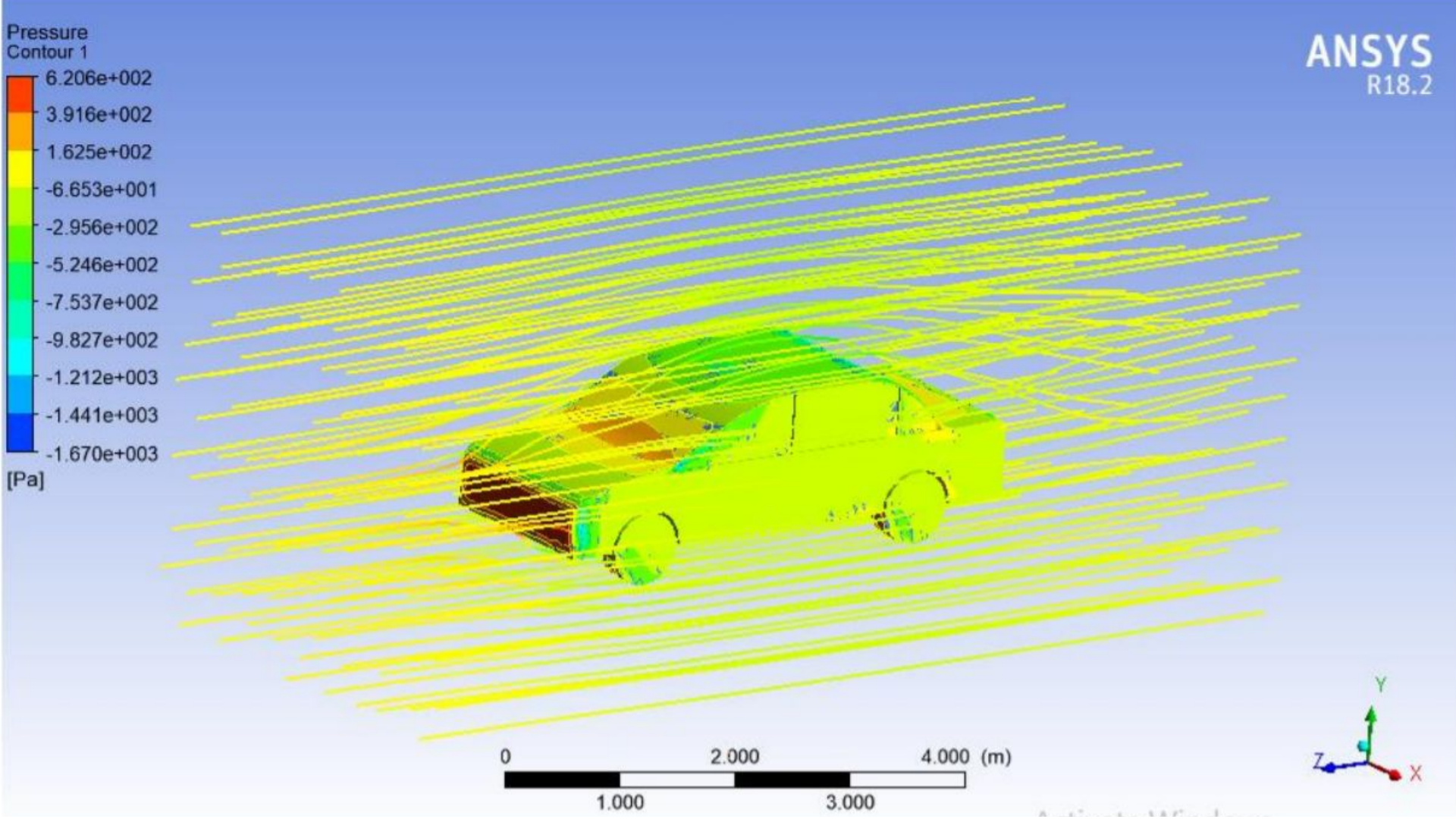
Table 1



Pressure Profile of the car and drag force calculation for 15° angle of attack

Conclusion

- Drag force effects the top speed and stopping distance.
- Sudden changes in slope on surface results in high pressure areas.
- A significant low pressure region was noticed just behind the vehicle body.
- The vertical and lateral forces can be neglected as they have no significant change on the vehicle handling parameters.
- Active aerodynamic elements, such as the rear wing, can be very effective in controlling the drag or downforce of the vehicle at higher speeds and thus increasing the driver control and comfort.


Pressure
Contour 1
6.206e+002
3.916e+002
1.625e+002
-6.653e+001
-2.956e+002
-5.246e+002
-7.537e+002
-9.827e+002
-1.212e+003
-1.441e+003
-1.670e+003
[Pa]
ANSYS
R18.2
0
2.000
4.000 (m)
1.000
3.000
Y
Z
X

THANK YOU!