# MTF236 Assignment 1

*Caster Lab*

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# Contents

# 1 Task 1

## 1.1 Without Aero package

When the vehicle was driven without aero package, the car understeered. This led to increase in the possibility of crashing at higher speeds.

(a) Lateral acceleration (b) Velocity

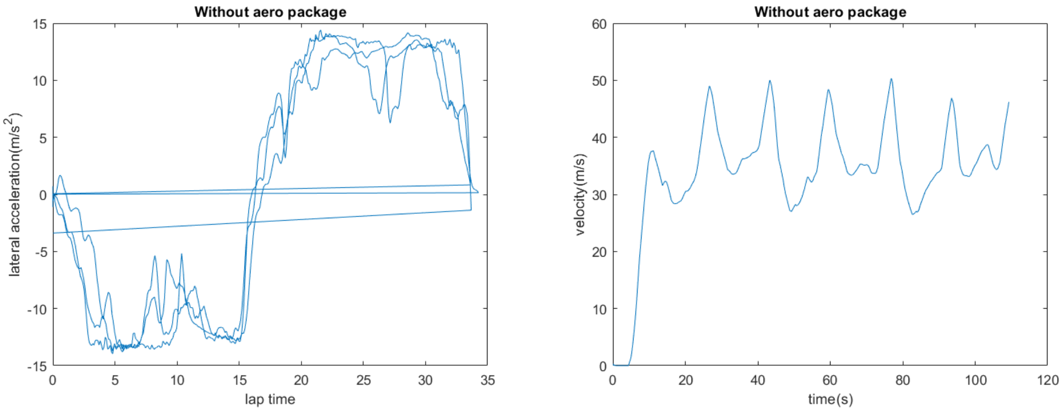



Figure 1: Without Aero package

## 1.2 With Aero package

When the vehicle was driven with aero package, the car oversteered. The steering effort was significantly high but the turn could be taken better. This led to faster driving without crashing.

(a) Lateral acceleration (b) Velocity

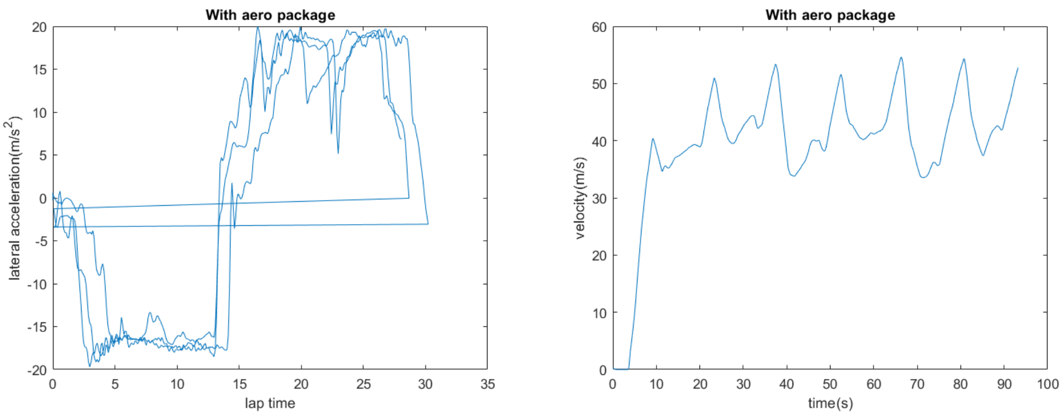



Figure 2: With aero package

## 2 Task 2

From the values in the table below it is observed that the lateral acceleration values are higher when the vehicle is incorporated with aero package which depicts that higher lateral accelerations could be handled by a car with aero package irrespective of the diameter of the turning circle. Without aero package, the vehicle is not capable of withstanding larger lateral acceleration values which makes driving hard at curves.

| | **Smaller circle** | | **Larger circle** | |
|---|---|---|---|---|
| | velocity (m/s) | lateral acceleration ($m/s^2$) | velocity (m/s) | lateral acceleration ($m/s^2$) |
| with aero package | 41.95 | 19.71 | 50.05 | 19.97 |
| without aero package | 33.45 | 13.97 | 40.57 | 14.41 |

In order to compare the data for a racing vehicle which is rarely in steady state condition, the maximum values which are close to the steady state situation is considered. When the vehicle is driven with aero package for both smaller and larger curves, the velocity can be found using the formula (derived from eqn 4),

$$Velocity, V = \sqrt{\frac{\mu \cdot m \cdot g}{\frac{m}{r} + \frac{1}{2} \cdot \mu \cdot \rho \cdot C_l \cdot A}} \tag{1}$$

## 3 Task 3

| | **Theoretical** | | **Test** | |
|---|---|---|---|---|
| | velocity | lateral acceleration | velocity | lateral acceleration |
| **Without** aero package | 38.93 | 14.71 | 40.57 | 14.41 |
| **With** aero package | 46.08 | 20.61 | 50.05 | 19.97 |

The vehicle is assumed to be in steady state cornering. The value used is -$C_L A_{fixed}$.

When the value is fixed, the difference in values between the velocities is 4 m/s and the lateral accelerations is found to be 0.64 $m/s^2$. When the same procedure is carried out for a lift neutral vehicle, the difference in values between the velocities is 0.64 m/s and the lateral accelerations is 0.3 $m/s^2$. The differences between the theoretical and test values are found to be reasonable.

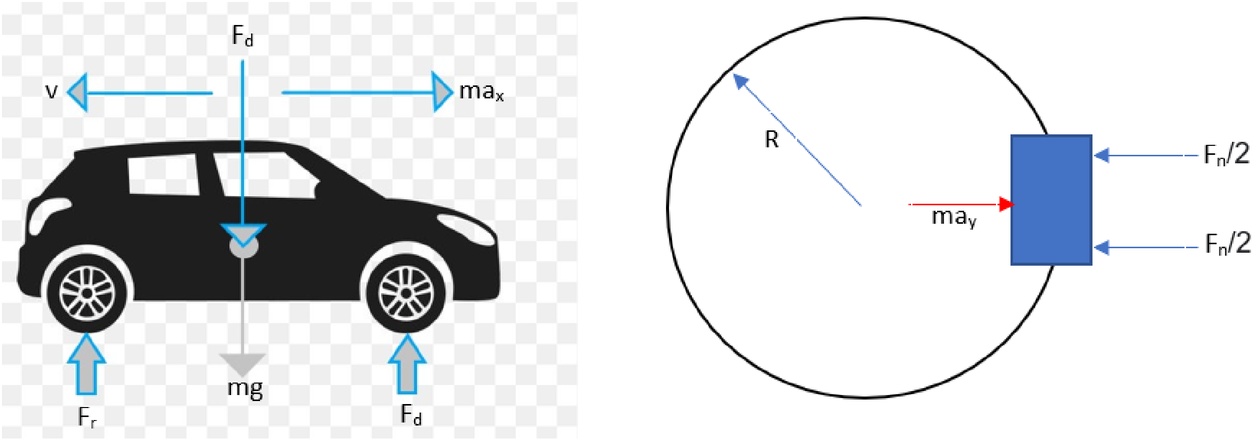
$$F_{centripetal} = \frac{m.v^2}{R} \quad ; \quad F_{friction} = \mu.N \tag{2}$$

where,

$$Normal force \quad N = m.g - \frac{1}{2}.C_L.A.\rho.v^2 \tag{3}$$

$$Therefore, \quad \frac{m.v^2}{R} = \mu(m.g - \frac{1}{2}.C_L.A.\rho.v^2) \tag{4}$$

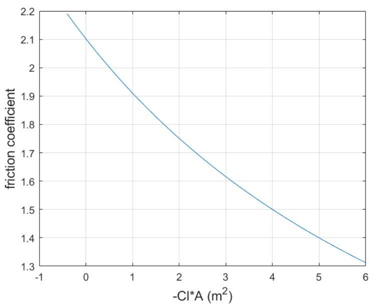
(a) Free body diagram



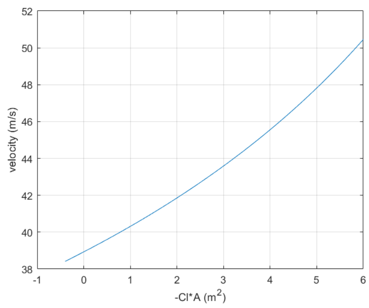

# 4 Task 4

All the parameters are considered constant in order to plot the friction coefficient, Velocity and mass with the varying -$C_L$A.

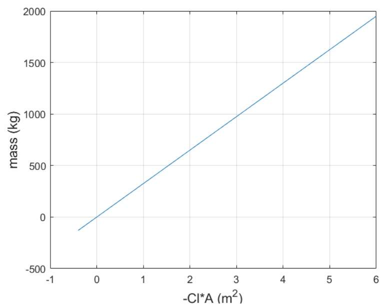
(a) Friction coefficient $\mu$




(b) Velocity V




(c) mass m




The -$C_L$A is varied between -$C_L A_{min}$ which is -0.4 $m^2$ and -$C_L A_{max}$ which is 6 $m^2$. The lift is found to be increasing as the friction coefficient decreases. Hence as the friction coefficient decreases the downforce is also found to be decreasing which can be dangerous if high. Also, it is observed that when the mass increases the lift also increases which reduces the downforce with increasing mass. All the three plots are linear.

$$Velocity, V = \sqrt{\frac{\mu \cdot m \cdot g}{\frac{m}{R} + \frac{1}{2} \cdot \mu \cdot \rho \cdot C_l \cdot A}} \tag{5}$$

$$mass, m = \frac{-\frac{1}{2} \cdot \rho \cdot \mu \cdot C_L \cdot A \cdot V^2 \cdot R}{V^2 - \mu \cdot g \cdot R} \tag{6}$$

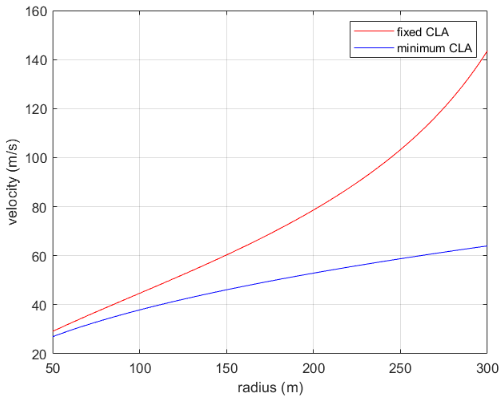
$$Frictioncoefficient, \mu = \frac{m \cdot V^2}{r(m \cdot g - \frac{1}{2} \cdot \rho \cdot C_L \cdot A \cdot V^2)} \tag{7}$$

# 5 Task 5

When a mass of 7kg is added, it is found that the value of -C$_L A$ which was 4 m$^2$ initially, increased to 4.0216 m$^2$. The speed will be reduced as the mass is increased. So more downforce is required to maintain the maximum cornering velocity. The equation used for calculation is:

$$C_L \cdot A = \frac{-\mu . m_{new} . g + \frac{m_{new} . v^2}{R}}{\frac{1}{2}\mu \rho v^2} \tag{8}$$

# 6 Task 6




As the downforce is high in case of -C$_L A_{fixed}$, it is possible for the vehicle to attain a high cornering velocity. But when the value of -C$_L A_{min}$ which is 0.4 m$^2$ is used, it is found that the vehicle cannot attain higher cornering velocities due to lack of downforce.

# 7 MATLAB Code

```
%% D1 with Aero

%% D1 with Aero

clc
clear all
with = load ('F:\001 CHALMERS\MTF236 - RVAD\CASTER\DRIVER2_with_Aero.mat');
figure()
plot(with.laptime,with.lateral_acceleration);
xlabel ('lap time');
ylabel('lateral acceleration(m/s^2)');
title('With aero package');
figure()
```

```
plot(with.time,with.velocity);
xlabel ('time(s)');
ylabel('velocity(m/s)');
title('With aero package');

[acc_s,b] = min(with.lateral_acceleration);
[acc_b,a] = max(with.lateral_acceleration);
vel_b = with.velocity(a);
vel_s = with.velocity(b);

%% D1 without aero

without = load ('F:\001 CHALMERS\MTF236 - RVAD\CASTER\DRIVER2_without_Aero.mat');
figure()
plot(without.laptime,without.lateral_acceleration);
xlabel ('lap time');
ylabel('lateral acceleration(m/s^2)');
title('Without aero package');
figure()
plot(without.time,without.velocity);
xlabel ('time(s)');
ylabel('velocity(m/s)');
title('Without aero package');
[b_acc_non,c] = max(without.lateral_acceleration);
b_vel_non = without.velocity(c);
[s_acc_non,d] = min(without.lateral_acceleration);
s_vel_non = without.velocity(d);


%% Data
mass = 1300; %kg
rad = 103; %m
rad_small = 77; %m
g=9.81; %m/s2
fric = 1.5 ;
fixed_CLA= 4;
min_CLA = -0.4;
max_CLA = 6;
dens_air = 1.205; %kg/m3
CLA = [min_CLA:0.02:max_CLA];
v= 46.0869; %m/s (calculated manually)
%% Task 4

new_fric = zeros(length(CLA));
for i=1:length(CLA)
```

```
    new_fric(i) = (v^2*mass)/((rad*mass*g)+(rad*0.5*dens_air*v^2*CLA(i)));
end
figure();
plot(CLA,new_fric(:,1));
xlabel('-Cl*A (m^2)');
ylabel('friction coefficient');
grid on;

new_mass = zeros(length(CLA));
for i=1:length(CLA)
    new_mass(i) = ((-0.5*dens_air*fric*v^2*CLA(i))*rad)/((fric*g*rad)-v^2);
end
 figure();
 plot(CLA,new_mass(:,1))
 xlabel('-Cl*A (m^2)');
ylabel('mass (kg)');
grid on;

new_v = zeros(length(CLA));
for i=1:length(CLA)
    new_v(i) = sqrt((fric*mass*g)/((mass/rad)+  (0.5*fric*dens_air*CLA(i))));
end
 figure();
 plot(CLA,new_v(:,1))
 xlabel('-Cl*A (m^2)');
 grid on;
ylabel('velocity (m/s)');

%% Task 5
mass_n = 1307;
%vel = sqrt((fric*mass_n*g)/((mass_n/rad)+(0.5*fric*dens_air*CLA(i))));
fixed_CLA_n = (((mass_n*v^2)/rad)-(fric*mass_n*g))/(0.5*v^2*dens_air*fric);
diff = fixed_CLA_n-fixed_CLA;

%% Task 6
radius = [50:1:300];
v6 = zeros(length(radius));

for i=1:length(radius)
    v6(i) = sqrt((fric*mass*g)/((mass/radius(i))-(0.5*fric*dens_air*fixed_CLA)));
end
figure();
plot(radius,v6(:,1),'r')
 xlabel('radius (m)');
ylabel('velocity (m/s)');
```

```
 grid on;
 hold on

v7 = zeros(length(radius));

for i=1:length(radius)
    v7(i) = sqrt((fric*mass*g)/((mass/radius(i))-(0.5*fric*dens_air*min_CLA)));
end

plot(radius,v7(:,1),'b')
 xlabel('radius (m)');
ylabel('velocity (m/s)');
legend('fixed CLA' ,'minimum CLA');
```