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Trailer Park Boys

Senior Capstone Design - Western Trailer

Dr. Beyerlein

48' No Nose Cone Data Processing

```
clc
clear
close all
```

Note - N: No Nose Cone

C: Nose Cone

B: Bull Nose

Reading Voltage Data from .xlsx files

```
Frequency = xlsread('Drag Data 48foot Trailer','48-foot No Nose Cone','B4:B11');
Display_Force = xlsread('Drag Data 48foot Trailer','48-foot No Nose Cone','E4:E11');
Display_Force_Hopper = xlsread('Drag Data 48foot Trailer','48-foot No Nose Cone','E16:E23');
Display_Force_Possum = xlsread('Drag Data 48foot Trailer','48-foot No Nose Cone','E28:E35');
```

Applying the scaling factor to the drag forces

```
Scale_Force = (Display_Force - 0.0036) ./ 0.9944;
Scale_Force_Hopper = (Display_Force_Hopper - 0.0036) ./ 0.9944;
Scale_Force_Possum = (Display_Force_Possum - 0.0036) ./ 0.9944;
```

Defining the Relationship between Frequency Drive and Wind Velocity

```
m_Vel = 1.2081; % (m/s) / Hz
b_Vel = -1.0632; % m/s

for n = 1:length(Frequency)
    V(n,1) = m_Vel*Frequency(n,1) + b_Vel; % m/s
end

V_mph = 2.23694*V;
```

Calculating the Coefficient of Drag on the Trailer

Constants

```
rho = 1.225; % kg/m^3
mu = 1.846e-5; % kg/m*s
w = 0.0678; % m (2.671 inches)
h = 0.0762; % m (3.000 inches)
L = 0.3815; % m (15.02 inches)
A = w*h; % m^2

% Calculation
C_Drag = (2*abs(Scale_Force)) ./ (rho*(V.^2)*A);
C_Drag_Hopper = (2*abs(Scale_Force_Hopper)) ./ (rho*(V.^2)*A);
C_Drag_Possum = (2*abs(Scale_Force_Possum)) ./ (rho*(V.^2)*A);
```

Determining the average Cd for each model

```
C_Drag_AvgN = mean(C_Drag);
C_Drag_Hopper_AvgN = mean(C_Drag_Hopper);
C_Drag_Possum_AvgN = mean(C_Drag_Possum);
```

Percent Changes in Drag Coefficient w.r.t base model

```
Hopper_ChangeN = (abs(C_Drag_AvgN - C_Drag_Hopper_AvgN) / C_Drag_AvgN) * 100;
Possum_ChangeN = (abs(C_Drag_AvgN - C_Drag_Possum_AvgN) / C_Drag_AvgN) * 100;
```

Uncertainty Analysis

```
U_FD = 0.00454; % N
U_V = 1; % m/s
U_rho = 0.0001; % kg/m^3
U_A = 0.00001; % m^2
CD_FD = 1 / ((1/2) * rho * A * V.^2);
```

```

%No undercarriage
CD_rho = (-Scale_Force)/((1/2)*rho^2*A*V.^2);
CD_A = (-Scale_Force)/((1/2)*rho*A^2*V.^2);
CD_V = (-2*Scale_Force)/((1/2)*rho*A*V.^3);
U_CD = ((CD_FD*U_FD).^2 + (CD_rho*U_rho).^2 + (CD_A*U_A).^2 + (CD_V*U_V).^2).^^(1/2);

%Hopper Bins
CD_rho_Hopper = (-Scale_Force_Hopper)/((1/2)*rho^2*A*V.^2);
CD_A_Hopper = (-Scale_Force_Hopper)/((1/2)*rho*A^2*V.^2);
CD_V_Hopper = (-2*Scale_Force_Hopper)/((1/2)*rho*A*V.^3);
U_CD_Hopper = ((CD_FD*U_FD).^2 + (CD_rho_Hopper*U_rho).^2 + (CD_A_Hopper*U_A).^2 + (CD_V_Hopper*U_V).^2).^^(1/2);

%Possum Belly
CD_rho_Possum = (-Scale_Force_Possum)/((1/2)*rho^2*A*V.^2);
CD_A_Possum = (-Scale_Force_Possum)/((1/2)*rho*A^2*V.^2);
CD_V_Possum = (-2*Scale_Force_Possum)/((1/2)*rho*A*V.^3);
U_CD_Possum = ((CD_FD*U_FD).^2 + (CD_rho_Possum*U_rho).^2 + (CD_A_Possum*U_A).^2 + (CD_V_Possum*U_V).^2).^^(1/2);

```

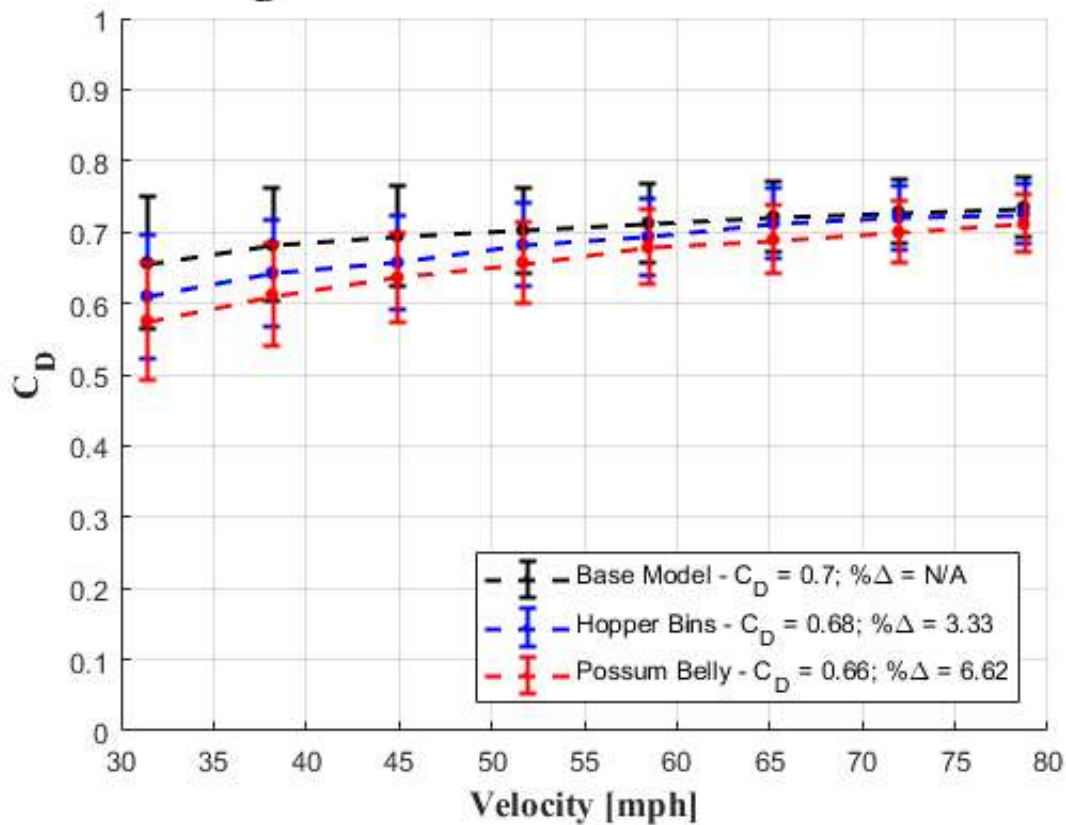
Plotting Results

```

figure(1)
set(gcf,'color','w')
% plot(V_mph,C_Drag,'k.--','Linewidth',2,'MarkerSize',30)
errorbar(V_mph,C_Drag,U_CD(:,1),'k.--','Linewidth',1.5,'MarkerSize',15)
hold on
% plot(V_mph,C_Drag_Hopper,'b.--','Linewidth',2,'MarkerSize',30)
errorbar(V_mph,C_Drag_Hopper,U_CD_Hopper(:,1),'b.--','Linewidth',1.5,'MarkerSize',15)
% plot(V_mph,C_Drag_Possum,'r.--','Linewidth',2,'MarkerSize',30)
errorbar(V_mph,C_Drag_Possum,U_CD_Possum(:,1),'r.--','Linewidth',1.5,'MarkerSize',15)
title('C_{D} of a 48'' Trailer with no Nose Cone','Fontname','Times',...
      'Fontweight','bold','FontSize',16)
xlabel('Velocity [mph]','Fontname','Times','Fontweight','bold','FontSize',13)
ylabel('C_{D}','Fontname','Times','Fontweight','bold','FontSize',13)
ylimits = [0 1];
ylim(ylimits)
legend('Location','southeast',['Base Model - C_{D} = ',num2str(C_Drag_AvgN,2),...
      '; %{\Delta} = N/A'], ['Hopper Bins - C_{D} = ',num2str(C_Drag_Hopper_AvgN,2),...
      '; %{\Delta} = ',num2str(Hopper_ChangeN,3)], ['Possum Belly - C_{D} = ',...
      num2str(C_Drag_Possum_AvgN,2), '; %{\Delta} = ',num2str(Possum_ChangeN,3)])
grid on
box off

```

C_D of a 48' Trailer with no Nose Cone



Emission Calculations

```

C1 = 117.8;
C2 = 1.78;
C3 = -9.48;
C4 = -0.00258;
C5 = 1.00;           %Tire Inflation System
TRRL = 4.6;         %Tire Rolling Resistance Level
WR = 655;           %Weight Reduction
h_48 = 2.92;        %m
w_48 = 2.49;        %m
A_48 = h_48*w_48;  %m^2

e_CO2_HopperN = (C1 + C2*TRRL + C3*(abs(C_Drag_AvgN - C_Drag_Hopper_AvgN)*A_48) ...
    + C4*WR)*C5    %gCO2/ton-mile
e_CO2_PossumN = (C1 + C2*TRRL + C3*(abs(C_Drag_AvgN - C_Drag_Possum_AvgN)*A_48) ...
    + C4*WR)*C5    %gCO2/ton-mile

FC_HopperN = (e_CO2_HopperN/10180)*1000 %gal_diesel/1000ton-mile
FC_PossumN = (e_CO2_PossumN/10180)*1000 %gal_diesel/1000ton-mile
    
```

e_CO2_HopperN =

122.6816

e_CO2_PossumN =

121.0863

FC_HopperN =

12.0512

FC_PossumN =

11.8945

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Trailer Park Boys

Senior Capstone Design - Western Trailer

Dr. Beyerlein

48' Nose Cone Data Processing

```
clc
clear
close all
```

Note - N: No Nose Cone

C: Nose Cone

B: Bull Nose

Reading Voltage Data from .xlsx files

```
Frequency = xlsread('Drag Data 48foot Trailer','48-foot Nose Cone','B4:B11');
Display_Force = xlsread('Drag Data 48foot Trailer','48-foot Nose Cone','E4:E11');
Display_Force_Hopper = xlsread('Drag Data 48foot Trailer','48-foot Nose Cone','E16:E23');
Display_Force_Possum = xlsread('Drag Data 48foot Trailer','48-foot Nose Cone','E28:E35');
```

Applying the scaling factor to the drag forces

```

Scale_Force = (Display_Force - 0.0036) ./ 0.9944;
Scale_Force_Hopper = (Display_Force_Hopper - 0.0036) ./ 0.9944;
Scale_Force_Possum = (Display_Force_Possum - 0.0036) ./ 0.9944;

```

Defining the Relationship between Frequency Drive and Wind Velocity

```

m_Vel = 1.2081; % (m/s) / Hz
b_Vel = -1.0632; % m/s

for n = 1:length(Frequency)
    V(n,1) = m_Vel*Frequency(n,1) + b_Vel; % m/s
end

V_mph = 2.23694*V;

```

Calculating the Coefficient of Drag on the Trailer

Constants

```

rho = 1.225; % kg/m^3
mu = 1.846e-5; % kg/m*s
w = 0.0678; % m (2.671 inches)
h = 0.0762; % m (3.000 inches)
L = 0.3815; % m (15.02 inches)
A = w*h; % m^2

% Calculation
C_Drag = (2*abs(Scale_Force)) ./ (rho*(V.^2)*A);
C_Drag_Hopper = (2*abs(Scale_Force_Hopper)) ./ (rho*(V.^2)*A);
C_Drag_Possum = (2*abs(Scale_Force_Possum)) ./ (rho*(V.^2)*A);

```

Determining the average Cd for each model

```

C_Drag_AvgC = mean(C_Drag);
C_Drag_Hopper_AvgC = mean(C_Drag_Hopper);
C_Drag_Possum_AvgC = mean(C_Drag_Possum);

```

Percent Changes in Drag Coefficient w.r.t base model

```

Hopper_ChangeC = (abs(C_Drag_AvgC - C_Drag_Hopper_AvgC) / C_Drag_AvgC) * 100;
Possum_ChangeC = (abs(C_Drag_AvgC - C_Drag_Possum_AvgC) / C_Drag_AvgC) * 100;

```

Uncertainty Analysis

```

U_FD = 0.00454; % N
U_V = 1; % m/s
U_rho = 0.0001; % kg/m^3
U_A = 0.00001; % m^2
CD_FD = 1 / ((1/2) * rho * A * V.^2);

```

```

%No undercarriage
CD_rho = (-Scale_Force)/((1/2)*rho^2*A*V.^2);
CD_A = (-Scale_Force)/((1/2)*rho*A^2*V.^2);
CD_V = (-2*Scale_Force)/((1/2)*rho*A*V.^3);
U_CD = ((CD_FD*U_FD).^2 + (CD_rho*U_rho).^2 + (CD_A*U_A).^2 + (CD_V*U_V).^2).^^(1/2);

%Hopper Bins
CD_rho_Hopper = (-Scale_Force_Hopper)/((1/2)*rho^2*A*V.^2);
CD_A_Hopper = (-Scale_Force_Hopper)/((1/2)*rho*A^2*V.^2);
CD_V_Hopper = (-2*Scale_Force_Hopper)/((1/2)*rho*A*V.^3);
U_CD_Hopper = ((CD_FD*U_FD).^2 + (CD_rho_Hopper*U_rho).^2 + (CD_A_Hopper*U_A).^2 + (CD_V_Hopper*U_V).^2).^^(1/2);

%Possum Belly
CD_rho_Possum = (-Scale_Force_Possum)/((1/2)*rho^2*A*V.^2);
CD_A_Possum = (-Scale_Force_Possum)/((1/2)*rho*A^2*V.^2);
CD_V_Possum = (-2*Scale_Force_Possum)/((1/2)*rho*A*V.^3);
U_CD_Possum = ((CD_FD*U_FD).^2 + (CD_rho_Possum*U_rho).^2 + (CD_A_Possum*U_A).^2 + (CD_V_Possum*U_V).^2).^^(1/2);

```

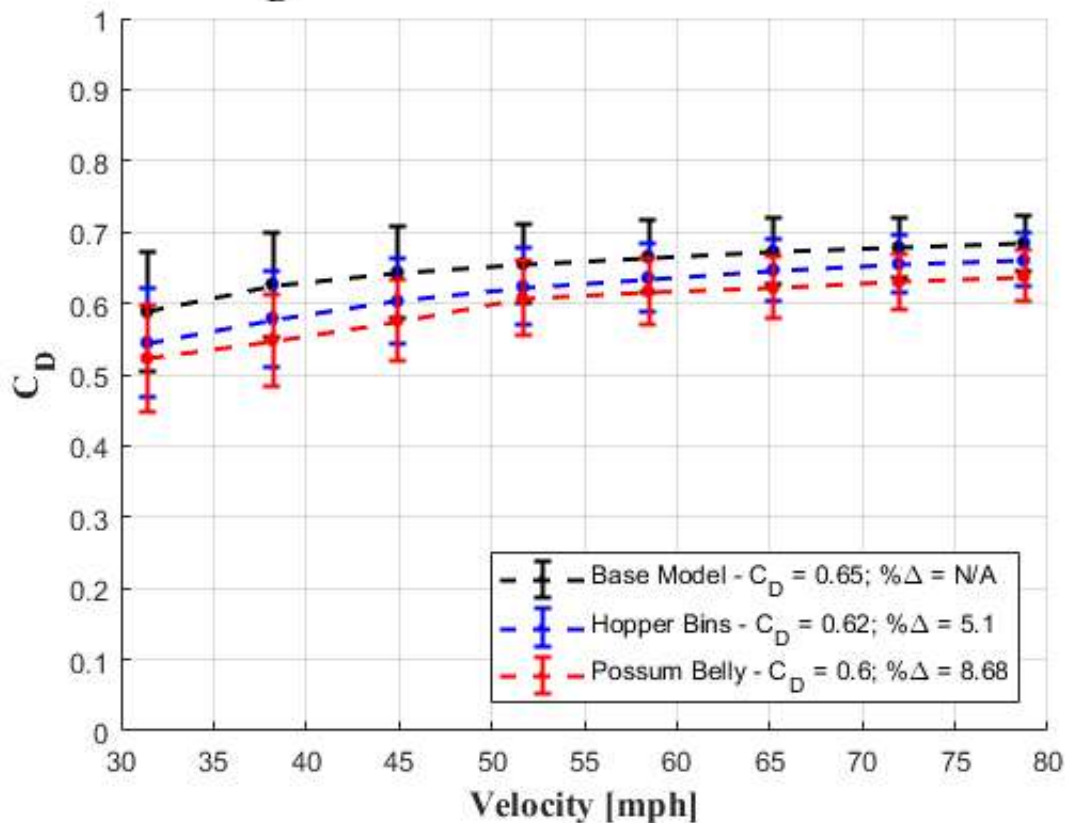
Plotting Results

```

figure(2)
set(gcf,'color','w')
% plot(V_mph,C_Drag,'k.--','Linewidth',2,'MarkerSize',30)
errorbar(V_mph,C_Drag,U_CD(:,1),'k.--','Linewidth',1.5,'MarkerSize',15)
hold on
% plot(V_mph,C_Drag_Hopper,'b.--','Linewidth',2,'MarkerSize',30)
errorbar(V_mph,C_Drag_Hopper,U_CD_Hopper(:,1),'b.--','Linewidth',1.5,'MarkerSize',15)
% plot(V_mph,C_Drag_Possum,'r.--','Linewidth',2,'MarkerSize',30)
errorbar(V_mph,C_Drag_Possum,U_CD_Possum(:,1),'r.--','Linewidth',1.5,'MarkerSize',15)
title('C_{D} of a 48'' Trailer with a Nose Cone','Fontname','Times',...
      'Fontweight','bold','FontSize',16)
xlabel('Velocity [mph]','Fontname','Times','Fontweight','bold','FontSize',13)
ylabel('C_{D}','Fontname','Times','Fontweight','bold','FontSize',13)
ylimits = [0 1];
ylim(ylimits)
legend('Location','southeast',['Base Model - C_{D} = ',num2str(C_Drag_AvgC,2),...
      '; %{\Delta} = N/A'], ['Hopper Bins - C_{D} = ',num2str(C_Drag_Hopper_AvgC,2),...
      '; %{\Delta} = ',num2str(Hopper_ChangeC,3)], ['Possum Belly - C_{D} = ',...
      num2str(C_Drag_Possum_AvgC,2), '; %{\Delta} = ',num2str(Possum_ChangeC,3)])
grid on
box off

```


C_D of a 48' Trailer with a Nose Cone



Emission Calculations

```

CD_BaseNNC = 0.7042;
C1 = 117.8;
C2 = 1.78;
C3 = -9.48;
C4 = -0.00258;
C5 = 1.00;           %Tire Inflation System
TRRL = 4.6;         %Tire Rolling Resistance Level
WR = 655;           %Weight Reduction
h_48 = 2.92;        %m
w_48 = 2.49;        %m
A_48 = h_48*w_48;  %m^2

e_CO2_C = (C1 + C2*TRRL + C3*(abs(CD_BaseNNC - C_Drag_AvgC)*A_48) ...
+ C4*WR)*C5 %gCO2/ton-mile
e_CO2_HopperC = (C1 + C2*TRRL + C3*(abs(CD_BaseNNC - C_Drag_Hopper_AvgC)*A_48) ...
+ C4*WR)*C5 %gCO2/ton-mile
e_CO2_PossumC = (C1 + C2*TRRL + C3*(abs(CD_BaseNNC - C_Drag_Possum_AvgC)*A_48) ...
+ C4*WR)*C5 %gCO2/ton-mile

FC_C = (e_CO2_C/10180)*1000 %gal_diesel/1000ton-mile
FC_HopperC = (e_CO2_HopperC/10180)*1000 %gal_diesel/1000ton-mile
FC_PossumC = (e_CO2_PossumC/10180)*1000 %gal_diesel/1000ton-mile
    
```

e_CO2_C =

120.6984

e_CO2_HopperC =

118.4087

e_CO2_PossumC =

116.7988

FC_C =

11.8564

FC_HopperC =

11.6315

FC_PossumC =

11.4734

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Trailer Park Boys

Senior Capstone Design - Western Trailer

Dr. Beyerlein

48' Bull Nose Data Processing

```
clc
clear
close all
```

Note - N: No Nose Cone

C: Nose Cone

B: Bull Nose

Reading Voltage Data from .xlsx files

```
Frequency = xlsread('Drag Data 48foot Trailer','48-foot Bull Nose','B4:B11');
Display_Force = xlsread('Drag Data 48foot Trailer','48-foot Bull Nose','E4:E11');
Display_Force_Hopper = xlsread('Drag Data 48foot Trailer','48-foot Bull Nose','E16:E23');
Display_Force_Possum = xlsread('Drag Data 48foot Trailer','48-foot Bull Nose','E28:E35');
```

Applying the scaling factor to the drag forces

```
Scale_Force = (Display_Force - 0.0036) ./ 0.9944;
Scale_Force_Hopper = (Display_Force_Hopper - 0.0036) ./ 0.9944;
Scale_Force_Possum = (Display_Force_Possum - 0.0036) ./ 0.9944;
```

Defining the Relationship between Frequency Drive and Wind Velocity

```
m_Vel = 1.2081; % (m/s) / Hz
b_Vel = -1.0632; % m/s

for n = 1:length(Frequency)
    V(n,1) = m_Vel*Frequency(n,1) + b_Vel; % m/s
end

V_mph = 2.23694*V;
```

Calculating the Coefficient of Drag on the Trailer

Constants

```
rho = 1.225; % kg/m^3
mu = 1.846e-5; % kg/m*s
w = 0.0678; % m (2.671 inches)
h = 0.0762; % m (3.000 inches)
L = 0.3815; % m (15.02 inches)
A = w*h; % m^2

% Calculation
C_Drag = (2*abs(Scale_Force)) ./ (rho*(V.^2)*A);
C_Drag_Hopper = (2*abs(Scale_Force_Hopper)) ./ (rho*(V.^2)*A);
C_Drag_Possum = (2*abs(Scale_Force_Possum)) ./ (rho*(V.^2)*A);
```

Determining the average Cd for each model

```
C_Drag_AvgB = mean(C_Drag);
C_Drag_Hopper_AvgB = mean(C_Drag_Hopper);
C_Drag_Possum_AvgB = mean(C_Drag_Possum);
```

Percent Changes in Drag Coefficient w.r.t base model

```
Hopper_ChangeB = (abs(C_Drag_AvgB - C_Drag_Hopper_AvgB) / C_Drag_AvgB) * 100;
Possum_ChangeB = (abs(C_Drag_AvgB - C_Drag_Possum_AvgB) / C_Drag_AvgB) * 100;
```

Uncertainty Analysis

```
U_FD = 0.00454; % N
U_V = 1; % m/s
U_rho = 0.0001; % kg/m^3
U_A = 0.00001; % m^2
CD_FD = 1 / ((1/2) * rho * A * V.^2);
```

```

%No Nose Cone
CD_rho = (-Scale_Force)./((1/2)*rho^2*A*V.^2);
CD_A = (-Scale_Force)./((1/2)*rho*A^2*V.^2);
CD_V = (-2*Scale_Force)./((1/2)*rho*A*V.^3);
U_CD = ((CD_FD*U_FD).^2 + (CD_rho*U_rho).^2 + (CD_A*U_A).^2 + (CD_V*U_V).^2).^^(1/2);

%Nose Cone
CD_rho_Hopper = (-Scale_Force_Hopper)./((1/2)*rho^2*A*V.^2);
CD_A_Hopper = (-Scale_Force_Hopper)./((1/2)*rho*A^2*V.^2);
CD_V_Hopper = (-2*Scale_Force_Hopper)./((1/2)*rho*A*V.^3);
U_CD_Hopper = ((CD_FD*U_FD).^2 + (CD_rho_Hopper*U_rho).^2 + (CD_A_Hopper*U_A).^2 + (CD_V_Hopper*U_V).^2).^^(1/2);

%Bull Nose
CD_rho_Possum = (-Scale_Force_Possum)./((1/2)*rho^2*A*V.^2);
CD_A_Possum = (-Scale_Force_Possum)./((1/2)*rho*A^2*V.^2);
CD_V_Possum = (-2*Scale_Force_Possum)./((1/2)*rho*A*V.^3);
U_CD_Possum = ((CD_FD*U_FD).^2 + (CD_rho_Possum*U_rho).^2 + (CD_A_Possum*U_A).^2 + (CD_V_Possum*U_V).^2).^^(1/2);

```

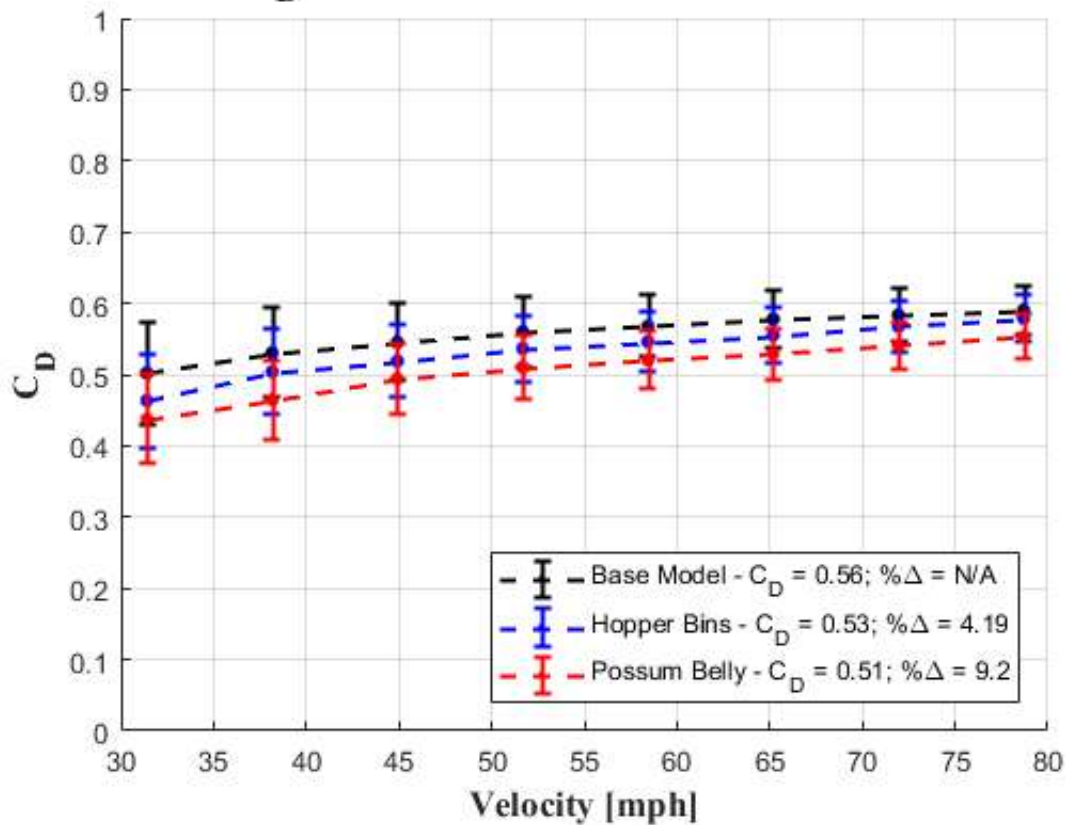
Plotting Results

```

figure(3)
set(gcf,'color','w')
% plot(V_mph,C_Drag,'k.--','Linewidth',2,'MarkerSize',30)
errorbar(V_mph,C_Drag,U_CD(:,1),'k.--','Linewidth',1.5,'MarkerSize',15)
hold on
% plot(V_mph,C_Drag_Hopper,'b.--','Linewidth',2,'MarkerSize',30)
errorbar(V_mph,C_Drag_Hopper,U_CD_Hopper(:,1),'b.--','Linewidth',1.5,'MarkerSize',15)
% plot(V_mph,C_Drag_Possum,'r.--','Linewidth',2,'MarkerSize',30)
errorbar(V_mph,C_Drag_Possum,U_CD_Possum(:,1),'r.--','Linewidth',1.5,'MarkerSize',15)
title('C_{D} of a 48'' Trailer with a Bull Nose','Fontname','Times',...
      'Fontweight','bold','FontSize',16)
xlabel('Velocity [mph]','Fontname','Times','Fontweight','bold','FontSize',13)
ylabel('C_{D}','Fontname','Times','Fontweight','bold','FontSize',13)
ylimits = [0 1];
ylim(ylimits)
legend('Location','southeast',['Base Model - C_{D} = ',num2str(C_Drag_AvgB,2)...
    ','; %{\Delta} = N/A'], ['Hopper Bins - C_{D} = ',num2str(C_Drag_Hopper_AvgB,2)...
    ','; %{\Delta} = ',num2str(Hopper_ChangeB,3)], ['Possum Belly - C_{D} = ',...
    num2str(C_Drag_Possum_AvgB,2),'; %{\Delta} = ',num2str(Possum_ChangeB,2)])
grid on
box off

```

C_D of a 48' Trailer with a Bull Nose



Emission Calculations

```

CD_BaseNNC = 0.7042;
C1 = 117.8;
C2 = 1.78;
C3 = -9.48;
C4 = -0.00258;
C5 = 1.00;           %Tire Inflation System
TRRL = 4.6;         %Tire Rolling Resistance Level
WR = 655;           %Weight Reduction
h_48 = 2.92;        %m
w_48 = 2.49;        %m
A_48 = h_48*w_48;  %m^2

e_CO2_B = (C1 + C2*TRRL + C3*(abs(CD_BaseNNC - C_Drag_AvgB)*A_48) ...
+ C4*WR)*C5 %gCO2/ton-mile
e_CO2_HopperB = (C1 + C2*TRRL + C3*(abs(CD_BaseNNC - C_Drag_Hopper_AvgB)*A_48) ...
+ C4*WR)*C5 %gCO2/ton-mile
e_CO2_PossumB = (C1 + C2*TRRL + C3*(abs(CD_BaseNNC - C_Drag_Possum_AvgB)*A_48) ...
+ C4*WR)*C5 %gCO2/ton-mile

FC_B = (e_CO2_B/10180)*1000 %gal_diesel/1000ton-mile
FC_HopperB = (e_CO2_HopperB/10180)*1000 %gal_diesel/1000ton-mile
FC_PossumB = (e_CO2_PossumB/10180)*1000 %gal_diesel/1000ton-mile
    
```

e_CO2_B =

114.1721

e_CO2_HopperB =

112.5609

e_CO2_PossumB =

110.6561

FC_B =

11.2153

FC_HopperB =

11.0571

FC_PossumB =

10.8700

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Trailer Park Boys

Senior Capstone Design - Western Trailer

Dr. Beyerlein

48' No Underbelly Attachments Data Processing

```
clc
clear
close all
```

Note - N: No Nose Cone

C: Nose Cone

B: Bull Nose

Reading Voltage Data from .xlsx files

```
Frequency = xlsread('Drag Data 48foot Trailer','48-foot Bull Nose','B4:B11');
Display_ForceN = xlsread('Drag Data 48foot Trailer','48-foot No Nose Cone','E4:E11');
Display_ForceC = xlsread('Drag Data 48foot Trailer','48-foot Nose Cone','E4:E11');
Display_ForceB = xlsread('Drag Data 48foot Trailer','48-foot Bull Nose','E4:E11');
```

Applying the scaling factor to the drag forces

```
Scale_ForceN = (Display_ForceN - 0.0036)./0.9944;
Scale_ForceC = (Display_ForceC - 0.0036)./0.9944;
Scale_ForceB = (Display_ForceB - 0.0036)./0.9944;
```

Defining the Relationship between Frequency Drive and Wind Velocity

```
m_Vel = 1.2081; % (m/s) / Hz
b_Vel = -1.0632; % m/s

for n = 1:length(Frequency)
    V(n,1) = m_Vel*Frequency(n,1) + b_Vel; % m/s
end

V_mph = 2.23694*V;
```

Calculating the Coefficient of Drag on the Trailer

Constants

```
rho = 1.225; % kg/m^3
mu = 1.846e-5; % kg/m*s
w = 0.0678; % m (2.671 inches)
h = 0.0762; % m (3.000 inches)
L = 0.3815; % m (15.02 inches)
A = w*h; % m^2

% Calculation
C_DragN = (2*abs(Scale_ForceN))./(rho*(V.^2)*A);
C_DragC = (2*abs(Scale_ForceC))./(rho*(V.^2)*A);
C_DragB = (2*abs(Scale_ForceB))./(rho*(V.^2)*A);
```

Determining the average Cd for each model

```
C_Drag_AvgN = mean(C_DragN);
C_Drag_AvgC = mean(C_DragC);
C_Drag_AvgB = mean(C_DragB);
```

Percent Changes in Drag Coefficient w.r.t base model

```
NoUnder_ChangeC = (abs(C_Drag_AvgN - C_Drag_AvgC)/C_Drag_AvgN)*100;
NoUnder_ChangeB = (abs(C_Drag_AvgN - C_Drag_AvgB)/C_Drag_AvgN)*100;
```

Uncertainty Analysis

```
U_FD = 0.00454; % N
U_V = 1; % m/s
U_rho = 0.0001; % kg/m^3
U_A = 0.00001; % m^2
CD_FD = 1/((1/2)*rho*A*V.^2);
```

```

%No Nose Cone
CD_rho_N = (-Scale_ForceN)/((1/2)*rho^2*A*V.^2);
CD_A_N = (-Scale_ForceN)/((1/2)*rho*A^2*V.^2);
CD_V_N = (-2*Scale_ForceN)/((1/2)*rho*A*V.^3);
U_CD_N = ((CD_FD*U_FD).^2 + (CD_rho_N*U_rho).^2 + (CD_A_N*U_A).^2 + (CD_V_N*U_V).^2).^(1/2);

%Nose Cone
CD_rho_C = (-Scale_ForceC)/((1/2)*rho^2*A*V.^2);
CD_A_C = (-Scale_ForceC)/((1/2)*rho*A^2*V.^2);
CD_V_C = (-2*Scale_ForceC)/((1/2)*rho*A*V.^3);
U_CD_C = ((CD_FD*U_FD).^2 + (CD_rho_C*U_rho).^2 + (CD_A_C*U_A).^2 + (CD_V_C*U_V).^2).^(1/2);

%Bull Nose
CD_rho_B = (-Scale_ForceB)/((1/2)*rho^2*A*V.^2);
CD_A_B = (-Scale_ForceB)/((1/2)*rho*A^2*V.^2);
CD_V_B = (-2*Scale_ForceB)/((1/2)*rho*A*V.^3);
U_CD_B = ((CD_FD*U_FD).^2 + (CD_rho_B*U_rho).^2 + (CD_A_B*U_A).^2 + (CD_V_B*U_V).^2).^(1/2);

```

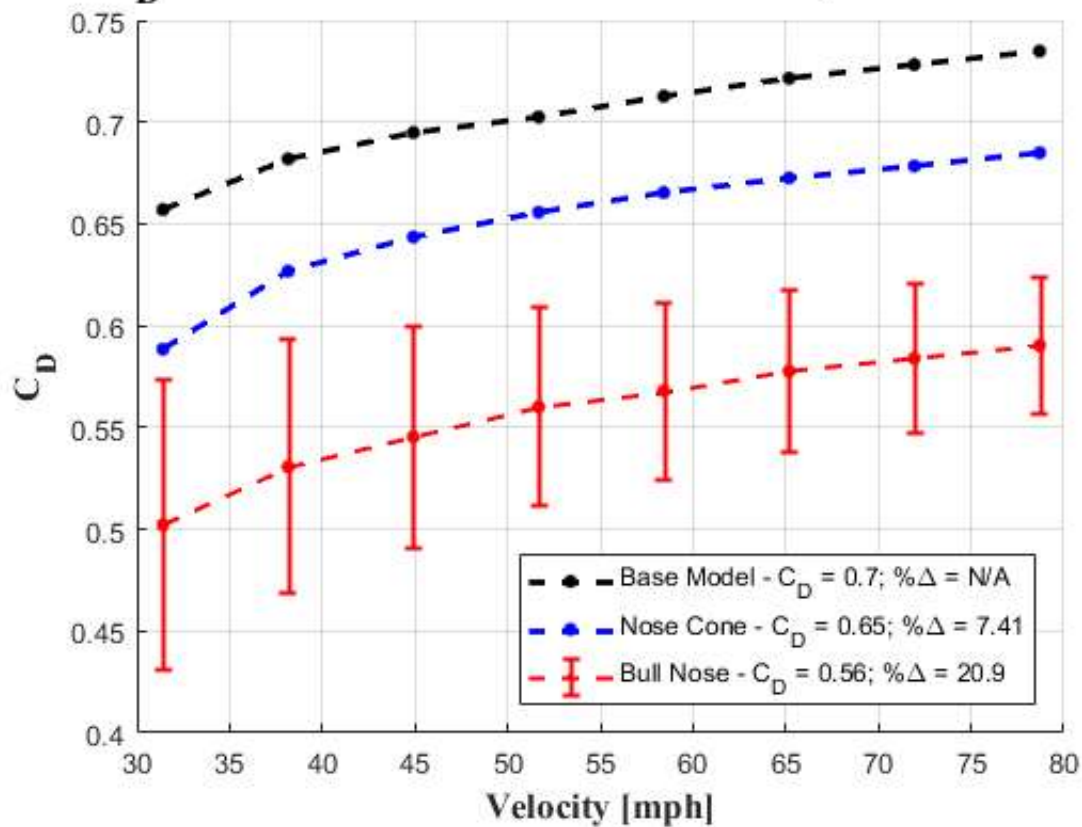
Plotting Results

```

figure(1)
set(gcf, 'color', 'w')
% errorbar(V_mph,C_DragN,U_CD_N(:,1), 'k.--', 'Linewidth',1.5, 'MarkerSize',15)
plot(V_mph,C_DragN, 'k.--', 'Linewidth',2, 'MarkerSize',15)
hold on
plot(V_mph,C_DragC, 'b.--', 'Linewidth',2, 'MarkerSize',15)
% errorbar(V_mph,C_DragC,U_CD_C(:,1), 'b.--', 'Linewidth',1.5, 'MarkerSize',15)
% plot(V_mph,C_DragB, 'r.--', 'Linewidth',2, 'MarkerSize',30)
errorbar(V_mph,C_DragB,U_CD_B(:,1), 'r.--', 'Linewidth',1.5, 'MarkerSize',15)
title('C_{D} of a 48" Trailer with no Underbelly Attachments', 'Fontname', 'Times', ...
      'Fontweight', 'bold', 'FontSize',16)
xlabel('Velocity [mph]', 'Fontname', 'Times', 'Fontweight', 'bold', 'FontSize',13)
ylabel('C_{D}', 'Fontname', 'Times', 'Fontweight', 'bold', 'FontSize',13)
ylimlimits = [0.4 0.75];
ylim(ylimlimits)
legend('Location', 'southeast', ['Base Model - C_{D} = ', num2str(C_Drag_AvgN,2), ...
      '; %{\Delta} = N/A'], ['Nose Cone - C_{D} = ', num2str(C_Drag_AvgC,2), ...
      '; %{\Delta} = ', num2str(NoUnder_ChangeC,3)], ['Bull Nose - C_{D} = ', ...
      num2str(C_Drag_AvgB,2), '; %{\Delta} = ', num2str(NoUnder_ChangeB,3)])
grid on
box off

```

C_D of a 48' Trailer with no Underbelly Attachments



Emission Calculations

```

CD_BaseNNC = 0.7042;
C1 = 117.8;
C2 = 1.78;
C3 = -9.48;
C4 = -0.00258;
C5 = 1.00;           %Tire Inflation System
TRRL = 4.6;         %Tire Rolling Resistance Level
WR = 655;           %Weight Reduction
h_48 = 2.92;        %m
w_48 = 2.49;        %m
A_48 = h_48*w_48;  %m^2

e_CO2_C = (C1 + C2*TRRL + C3*(abs(CD_BaseNNC - C_Drag_AvgC)*A_48) ...
+ C4*WR)*C5 %gCO2/ton-mile
e_CO2_B = (C1 + C2*TRRL + C3*(abs(CD_BaseNNC - C_Drag_AvgB)*A_48) ...
+ C4*WR)*C5 %gCO2/ton-mile

FC_C = (e_CO2_C/10180)*1000 %gal_diesel/1000ton-mile
FC_B = (e_CO2_B/10180)*1000 %gal_diesel/1000ton-mile
    
```

e_CO2_C =

120.6984

e_CO2_B =

114.1721

FC_C =

11.8564

FC_B =

11.2153

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Trailer Park Boys

Senior Capstone Design - Western Trailer

Dr. Beyerlein

48' Hopper Bin Attachments Data Processing

```
clc
clear
close all
```

Note - N: No Nose Cone

C: Nose Cone

B: Bull Nose

Reading Voltage Data from .xlsx files

```
Frequency = xlsread('Drag Data 48foot Trailer','48-foot Bull Nose','B4:B11');
Display_Force_HopperN = xlsread('Drag Data 48foot Trailer','48-foot No Nose Cone','E16:E23');
Display_Force_HopperC = xlsread('Drag Data 48foot Trailer','48-foot Nose Cone','E16:E23');
Display_Force_HopperB = xlsread('Drag Data 48foot Trailer','48-foot Bull Nose','E16:E23');
```

Applying the scaling factor to the drag forces

```
Scale_Force_HopperN = (Display_Force_HopperN - 0.0036) ./ 0.9944;
Scale_Force_HopperC = (Display_Force_HopperC - 0.0036) ./ 0.9944;
Scale_Force_HopperB = (Display_Force_HopperB - 0.0036) ./ 0.9944;
```

Defining the Relationship between Frequency Drive and Wind Velocity

```
m_Vel = 1.2081; % (m/s) / Hz
b_Vel = -1.0632; % m/s

for n = 1:length(Frequency)
    V(n,1) = m_Vel*Frequency(n,1) + b_Vel; % m/s
end

V_mph = 2.23694*V;
```

Calculating the Coefficient of Drag on the Trailer

Constants

```
rho = 1.225; % kg/m^3
mu = 1.846e-5; % kg/m*s
w = 0.0678; % m (2.671 inches)
h = 0.0762; % m (3.000 inches)
L = 0.3815; % m (15.02 inches)
A = w*h; % m^2

% Calculation
C_Drag_HopperN = (2*abs(Scale_Force_HopperN)) ./ (rho*(V.^2)*A);
C_Drag_HopperC = (2*abs(Scale_Force_HopperC)) ./ (rho*(V.^2)*A);
C_Drag_HopperB = (2*abs(Scale_Force_HopperB)) ./ (rho*(V.^2)*A);
```

Determining the average Cd for each model

```
C_Drag_Hopper_AvgN = mean(C_Drag_HopperN);
C_Drag_Hopper_AvgC = mean(C_Drag_HopperC);
C_Drag_Hopper_AvgB = mean(C_Drag_HopperB);
```

Percent Changes in Drag Coefficient w.r.t base model

```
Hopper_ChangeC = (abs(C_Drag_Hopper_AvgN - C_Drag_Hopper_AvgC) / C_Drag_Hopper_AvgN) * 100;
Hopper_ChangeB = (abs(C_Drag_Hopper_AvgN - C_Drag_Hopper_AvgB) / C_Drag_Hopper_AvgN) * 100;
```

Uncertainty Analysis

```
U_FD = 0.00454; % N
U_V = 1; % m/s
U_rho = 0.0001; % kg/m^3
U_A = 0.00001; % m^2
CD_FD = 1 / ((1/2) * rho * A * V.^2);
```

```

%No Nose Cone
CD_rho_HopperN = (-Scale_Force_HopperN)/((1/2)*rho^2*A*V.^2);
CD_A_HopperN = (-Scale_Force_HopperN)/((1/2)*rho*A^2*V.^2);
CD_V_HopperN = (-2*Scale_Force_HopperN)/((1/2)*rho*A*V.^3);
U_CD_HopperN = ((CD_FD*U_FD).^2 + (CD_rho_HopperN*U_rho).^2 + (CD_A_HopperN*U_A).^2 + (CD_V_HopperN*U_V).^2).^^(1/2);

%Nose Cone
CD_rho_HopperC = (-Scale_Force_HopperC)/((1/2)*rho^2*A*V.^2);
CD_A_HopperC = (-Scale_Force_HopperC)/((1/2)*rho*A^2*V.^2);
CD_V_HopperC = (-2*Scale_Force_HopperC)/((1/2)*rho*A*V.^3);
U_CD_HopperC = ((CD_FD*U_FD).^2 + (CD_rho_HopperC*U_rho).^2 + (CD_A_HopperC*U_A).^2 + (CD_V_HopperC*U_V).^2).^^(1/2);

%Bull Nose
CD_rho_HopperB = (-Scale_Force_HopperB)/((1/2)*rho^2*A*V.^2);
CD_A_HopperB = (-Scale_Force_HopperB)/((1/2)*rho*A^2*V.^2);
CD_V_HopperB = (-2*Scale_Force_HopperB)/((1/2)*rho*A*V.^3);
U_CD_HopperB = ((CD_FD*U_FD).^2 + (CD_rho_HopperB*U_rho).^2 + (CD_A_HopperB*U_A).^2 + (CD_V_HopperB*U_V).^2).^^(1/2);

```

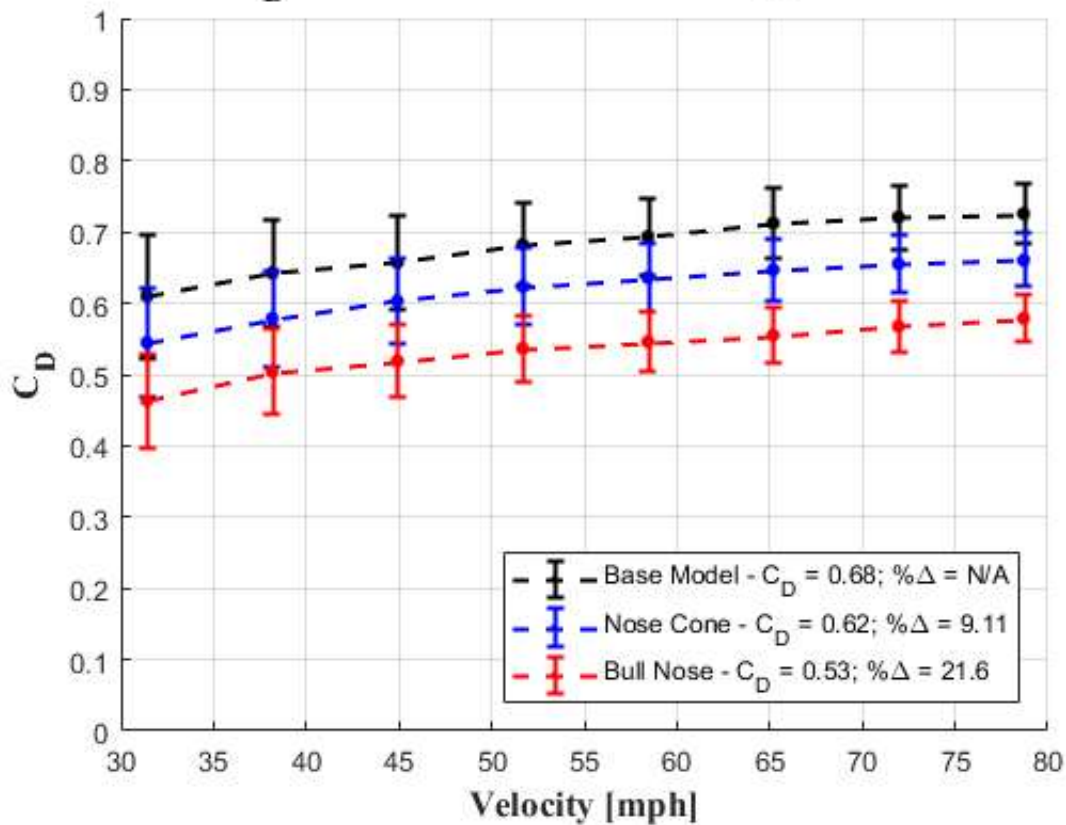
Plotting Results

```

figure(2)
set(gcf,'color','w')
% plot(V_mph,C_Drag_HopperN,'k.--','Linewidth',2,'MarkerSize',30)
errorbar(V_mph,C_Drag_HopperN,U_CD_HopperN(:,1),'k.--','Linewidth',1.5,'MarkerSize',15)
hold on
% plot(V_mph,C_Drag_HopperC,'b.--','Linewidth',2,'MarkerSize',30)
errorbar(V_mph,C_Drag_HopperC,U_CD_HopperC(:,1),'b.--','Linewidth',1.5,'MarkerSize',15)
% plot(V_mph,C_Drag_HopperB,'r.--','Linewidth',2,'MarkerSize',30)
errorbar(V_mph,C_Drag_HopperB,U_CD_HopperB(:,1),'r.--','Linewidth',1.5,'MarkerSize',15)
title('C_{D} of a 48'' Trailer with Hopper Bins','Fontname','Times',...
      'Fontweight','bold','FontSize',16)
xlabel('Velocity [mph]','Fontname','Times','Fontweight','bold','FontSize',13)
ylabel('C_{D}','Fontname','Times','Fontweight','bold','FontSize',13)
ylimits = [0 1];
ylim(ylimits)
legend('Location','southeast',['Base Model - C_{D} = ',num2str(C_Drag_Hopper_AvgN,2)...
    ,'; %{\Delta} = N/A'], ['Nose Cone - C_{D} = ',num2str(C_Drag_Hopper_AvgC,2)...
    ,'; %{\Delta} = ',num2str(Hopper_ChangeC,3)], ['Bull Nose - C_{D} = ',...
    num2str(C_Drag_Hopper_AvgB,2), '; %{\Delta} = ',num2str(Hopper_ChangeB,3)])
grid on
box off

```

C_D of a 48' Trailer with Hopper Bins



Emission Calculations

```

CD_BaseNNC = 0.7042;
C1 = 117.8;
C2 = 1.78;
C3 = -9.48;
C4 = -0.00258;
C5 = 1.00;           %Tire Inflation System
TRRL = 4.6;         %Tire Rolling Resistance Level
WR = 655;           %Weight Reduction
h_48 = 2.92;        %m
w_48 = 2.49;        %m
A_48 = h_48*w_48;  %m^2

e_CO2_HopperC = (C1 + C2*TRRL + C3*(abs(CD_BaseNNC - C_Drag_Hopper_AvgC)*A_48) ...
    + C4*WR)*C5 %gCO2/ton-mile
e_CO2_HopperB = (C1 + C2*TRRL + C3*(abs(CD_BaseNNC - C_Drag_Hopper_AvgB)*A_48) ...
    + C4*WR)*C5 %gCO2/ton-mile

FC_HopperC = (e_CO2_HopperC/10180)*1000 %gal_diesel/1000ton-mile
FC_HopperB = (e_CO2_HopperB/10180)*1000 %gal_diesel/1000ton-mile
    
```

e_CO2_HopperC =

118.4087

e_CO2_HopperB =

112.5609

FC_HopperC =

11.6315

FC_HopperB =

11.0571

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Trailer Park Boys

Senior Capstone Design - Western Trailer

Dr. Beyerlein

48' Possum Belly Data Processing

```
clc
clear
close all
```

Note - N: No Nose Cone

C: Nose Cone

B: Bull Nose

Reading Voltage Data from .xlsx files

```
Frequency = xlsread('Drag Data 48foot Trailer','48-foot Bull Nose','B4:B11');
Display_Force_PossumN = xlsread('Drag Data 48foot Trailer','48-foot No Nose Cone','E28:E35');
Display_Force_PossumC = xlsread('Drag Data 48foot Trailer','48-foot Nose Cone','E28:E35');
Display_Force_PossumB = xlsread('Drag Data 48foot Trailer','48-foot Bull Nose','E28:E35');
```

Applying the scaling factor to the drag forces

```
Scale_Force_PossumN = (Display_Force_PossumN - 0.0036) ./ 0.9944;
Scale_Force_PossumC = (Display_Force_PossumC - 0.0036) ./ 0.9944;
Scale_Force_PossumB = (Display_Force_PossumB - 0.0036) ./ 0.9944;
```

Defining the Relationship between Frequency Drive and Wind Velocity

```
m_Vel = 1.2081; % (m/s) / Hz
b_Vel = -1.0632; % m/s

for n = 1:length(Frequency)
    V(n,1) = m_Vel*Frequency(n,1) + b_Vel; % m/s
end

V_mph = 2.23694*V;
```

Calculating the Coefficient of Drag on the Trailer

Constants

```
rho = 1.225; % kg/m^3
mu = 1.846e-5; % kg/m*s
w = 0.0678; % m (2.671 inches)
h = 0.0762; % m (3.000 inches)
L = 0.3815; % m (15.02 inches)
A = w*h; % m^2

% Calculation
C_Drag_PossumN = (2*abs(Scale_Force_PossumN)) ./ (rho*(V.^2)*A);
C_Drag_PossumC = (2*abs(Scale_Force_PossumC)) ./ (rho*(V.^2)*A);
C_Drag_PossumB = (2*abs(Scale_Force_PossumB)) ./ (rho*(V.^2)*A);
```

Determining the average Cd for each model

```
C_Drag_Possum_AvgN = mean(C_Drag_PossumN);
C_Drag_Possum_AvgC = mean(C_Drag_PossumC);
C_Drag_Possum_AvgB = mean(C_Drag_PossumB);
```

Percent Changes in Drag Coefficient w.r.t base model

```
Possum_ChangeC = (abs(C_Drag_Possum_AvgN - C_Drag_Possum_AvgC) / C_Drag_Possum_AvgN) * 100;
Possum_ChangeB = (abs(C_Drag_Possum_AvgN - C_Drag_Possum_AvgB) / C_Drag_Possum_AvgN) * 100;
```

Uncertainty Analysis

```
U_FD = 0.00454; % N
U_V = 1; % m/s
U_rho = 0.0001; % kg/m^3
U_A = 0.00001; % m^2
CD_FD = 1 / ((1/2) * rho * A * V.^2);
```

```

%No Nose Cone
CD_rho_PossumN = (-Scale_Force_PossumN)/((1/2)*rho^2*A*V.^2);
CD_A_PossumN = (-Scale_Force_PossumN)/((1/2)*rho*A^2*V.^2);
CD_V_PossumN = (-2*Scale_Force_PossumN)/((1/2)*rho*A*V.^3);
U_CD_PossumN = ((CD_FD*U_FD).^2 + (CD_rho_PossumN*U_rho).^2 + (CD_A_PossumN*U_A).^2 + (CD_V_PossumN*U_V).^2).^^(1/2);

%Nose Cone
CD_rho_PossumC = (-Scale_Force_PossumC)/((1/2)*rho^2*A*V.^2);
CD_A_PossumC = (-Scale_Force_PossumC)/((1/2)*rho*A^2*V.^2);
CD_V_PossumC = (-2*Scale_Force_PossumC)/((1/2)*rho*A*V.^3);
U_CD_PossumC = ((CD_FD*U_FD).^2 + (CD_rho_PossumC*U_rho).^2 + (CD_A_PossumC*U_A).^2 + (CD_V_PossumC*U_V).^2).^^(1/2);

%Bull Nose
CD_rho_PossumB = (-Scale_Force_PossumB)/((1/2)*rho^2*A*V.^2);
CD_A_PossumB = (-Scale_Force_PossumB)/((1/2)*rho*A^2*V.^2);
CD_V_PossumB = (-2*Scale_Force_PossumB)/((1/2)*rho*A*V.^3);
U_CD_PossumB = ((CD_FD*U_FD).^2 + (CD_rho_PossumB*U_rho).^2 + (CD_A_PossumB*U_A).^2 + (CD_V_PossumB*U_V).^2).^^(1/2);

```

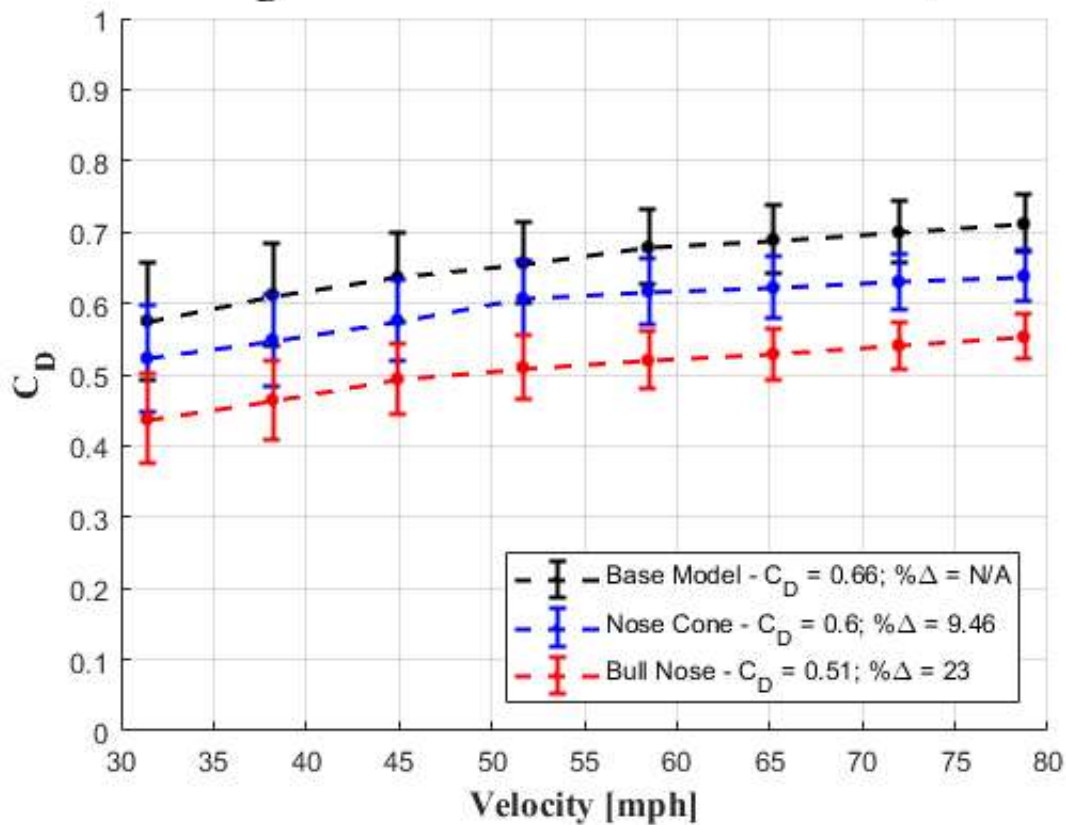
Plotting Results

```

figure(3)
set(gcf,'color','w')
% plot(V_mph,C_Drag_PossumN,'k.--','Linewidth',2,'MarkerSize',30)
errorbar(V_mph,C_Drag_PossumN,U_CD_PossumN(:,1),'k.--','Linewidth',1.5,'MarkerSize',15)
hold on
% plot(V_mph,C_Drag_PossumC,'b.--','Linewidth',2,'MarkerSize',30)
errorbar(V_mph,C_Drag_PossumC,U_CD_PossumC(:,1),'b.--','Linewidth',1.5,'MarkerSize',15)
% plot(V_mph,C_Drag_PossumB,'r.--','Linewidth',2,'MarkerSize',30)
errorbar(V_mph,C_Drag_PossumB,U_CD_PossumB(:,1),'r.--','Linewidth',1.5,'MarkerSize',15)
title('C_{D} of a 48" Trailer with Possum Belly','Fontname','Times',...
      'Fontweight','bold','FontSize',16)
xlabel('Velocity [mph]','Fontname','Times','Fontweight','bold','FontSize',13)
ylabel('C_{D}','Fontname','Times','Fontweight','bold','FontSize',13)
ylimits = [0 1];
ylim(ylimits)
legend('Location','southeast',['Base Model - C_{D} = ',num2str(C_Drag_Possum_AvgN,2),...
      '; %{\Delta} = N/A'], ['Nose Cone - C_{D} = ',num2str(C_Drag_Possum_AvgC,2),...
      '; %{\Delta} = ',num2str(Possum_ChangeC,3)], ['Bull Nose - C_{D} = ',...
      num2str(C_Drag_Possum_AvgB,2), '; %{\Delta} = ',num2str(Possum_ChangeB,3)])
grid on
box off

```

C_D of a 48' Trailer with Possum Belly



Emission Calculations

```

CD_BaseNNC = 0.7042;
C1 = 76.1;
C2 = 1.67;
C3 = -5.82;
C4 = -0.00103;
C5 = 1.00;           %Tire Inflation System
TRRL = 4.6;         %Tire Rolling Resistance Level
WR = 655;           %Weight Reduction
h_48 = 2.92;        %m
w_48 = 2.49;        %m
A_48 = h_48*w_48;  %m^2

e_CO2_PossumN = (C1 + C2*TRRL + C3*(abs(CD_BaseNNC - C_Drag_Possum_AvgN)*A_48) ...
    + C4*WR)*C5 %gCO2/ton-mile
e_CO2_PossumC = (C1 + C2*TRRL + C3*(abs(CD_BaseNNC - C_Drag_Possum_AvgC)*A_48) ...
    + C4*WR)*C5 %gCO2/ton-mile
e_CO2_PossumB = (C1 + C2*TRRL + C3*(abs(CD_BaseNNC - C_Drag_Possum_AvgB)*A_48) ...
    + C4*WR)*C5 %gCO2/ton-mile

FC_PossumN = (e_CO2_PossumN/10180)*1000 %gal_diesel/1000ton-mile
FC_PossumC = (e_CO2_PossumC/10180)*1000 %gal_diesel/1000ton-mile
FC_PossumB = (e_CO2_PossumB/10180)*1000 %gal_diesel/1000ton-mile
    
```

e_CO2_PossumN =

81.1351

e_CO2_PossumC =

78.5034

e_CO2_PossumB =

74.7322

FC_PossumN =

7.9701

FC_PossumC =

7.7115

FC_PossumB =

7.3411