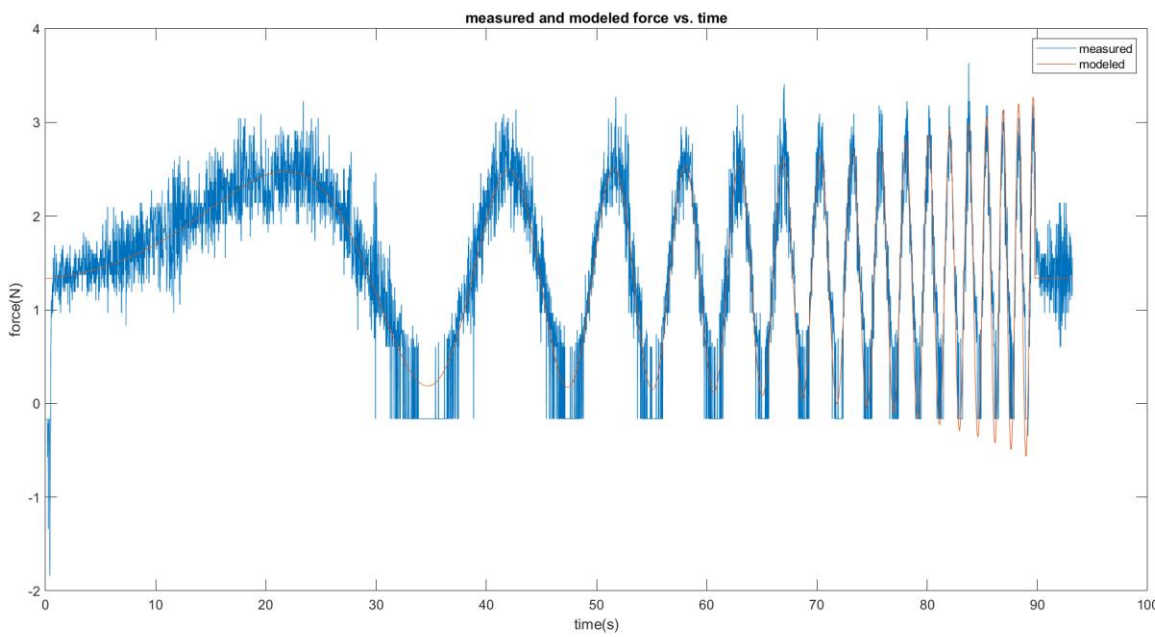
ME 494 – Robotics Systems Identification

HW #2: Due Wednesday, September 7th, 2022

Late homework will be subject to a 10% penalty per day

1. Using the data provided on Canvas (MotorData.mat) from a brushless motor and propeller attached to load cell, perform a least squares estimation. Data was collected with an automated logarithmic frequency sweep. You are free to create the model structure (it is recommended to look into motor differential equation models for assistance); however, you **must** use the motor thrust (force) as the dependent variable (z). Create a plot showing the dependent variable (force) and the estimated output (plot z and y hat versus time). An example of the model vs. measured is shown below. **You must have an $R^2 > 0.8$ (R^2 calculation is problem 5, but this will help to make sure you are using a sufficiently good model).**

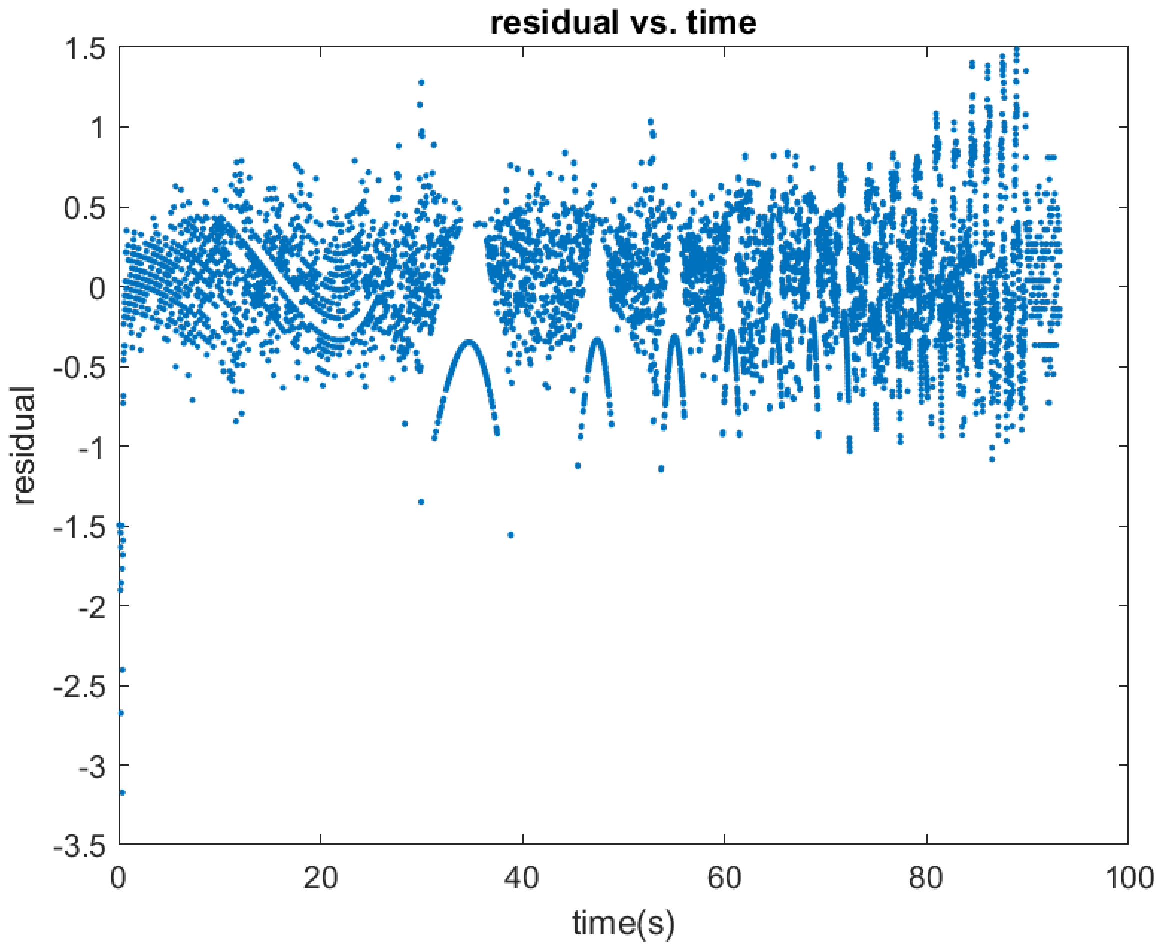


2. Show your **model structure** and the **associated estimated coefficients** used for Problem 1. You must also calculate the confidence interval on the estimated coefficients. Show in table form for simplicity (structure example below).

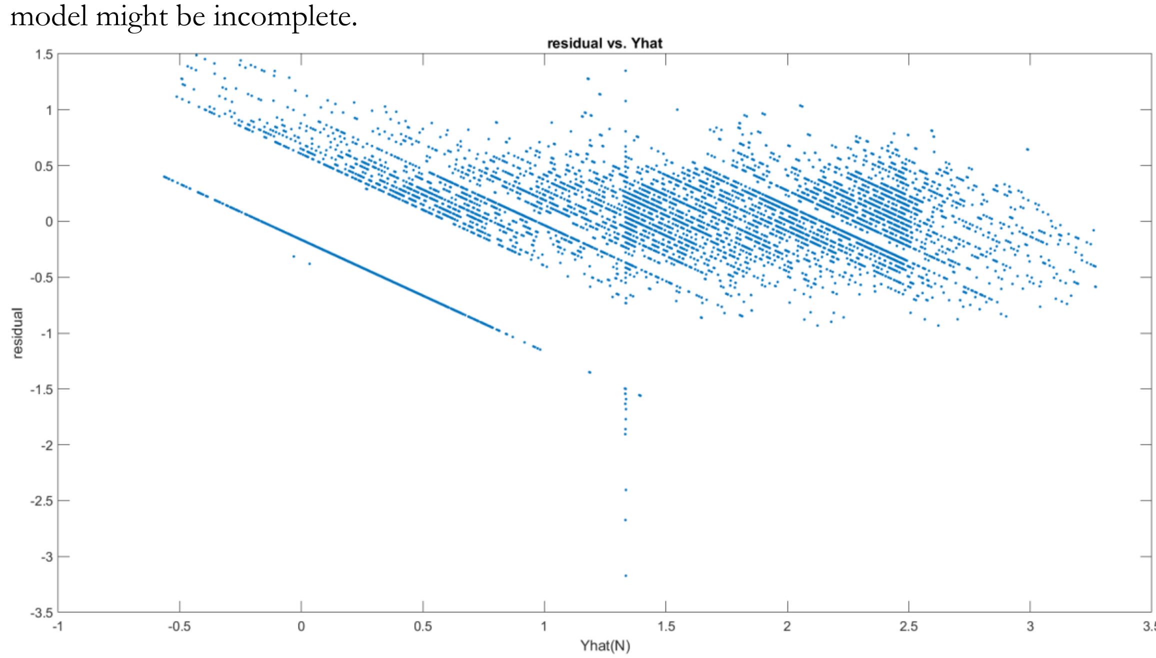
```
The model is: Y_hat = T_hat(1) * thr + T_hat(2) * deriv(thr,.01) + T_hat(3)

T =

  3×4 table

    param      T_hat      T_hat_confid    percent_T_hat_confid
    _____     ______      ____________    ____________________

    {'A'}       3.81       0.0021038             0.055219
    {'B'}     -1.059        0.000626            -0.059113
    {'C'}    -4.3803       0.0050453             -0.11518
```

Parameter	Estimated Value	Confidence Interval	Confidence Interval Percent
A	3.81	± 0.0021	± 5.5%
B	-1.06	± 0.0006	± 5.9%
C	-4.38	± 0.005	± 11.5%

3. Analyze the residuals as discussed in class. Describe any interesting things you see in the data. You need two plots for this problem.

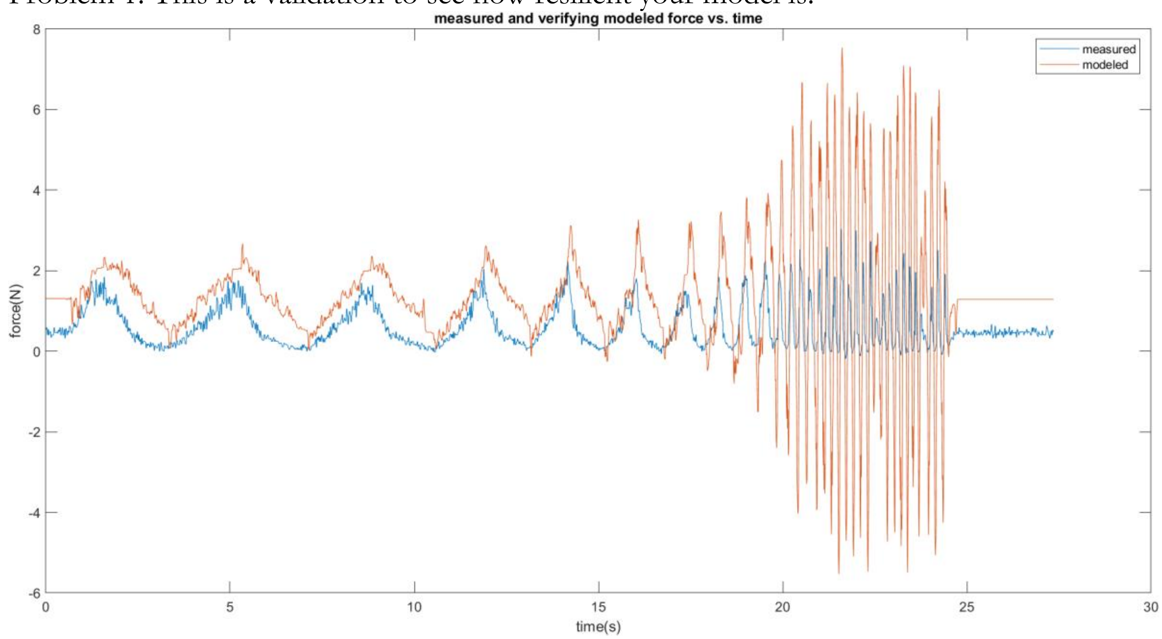


I would expect to see the residual to not vary much through the time interval but it seems as though there is some growth after 80 seconds. This might be because the model might be incomplete.



I would expect to see the residual to not vary much as Y_hat grows but it seems as though there is some inconsistent trend in the residuals associated Y_hat values between -1 and 1. This might be because the model might be incomplete.

4. Now using the validation dataset on Canvas (MotorData_Verify.mat), use your model to estimate the output thrust. Plot the measured and predicted thrust as in Problem 1. This is a validation to see how resilient your model is.

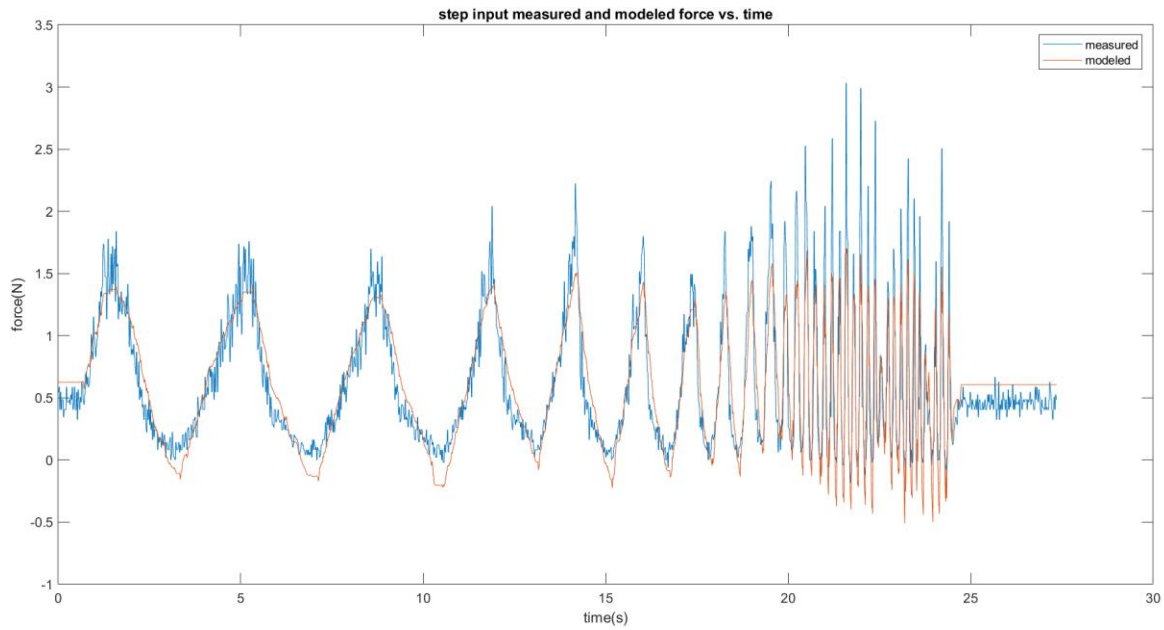


5. Calculate the coefficient of determination for the frequency sweep and the step input model prediction. How do the sweep (estimation fit) and the verification fit compare?

```
The frequency sweep R squared value is:

R_sq =

    0.8327

The step input R squared value is:

R_sq2 =

    3.0559
```

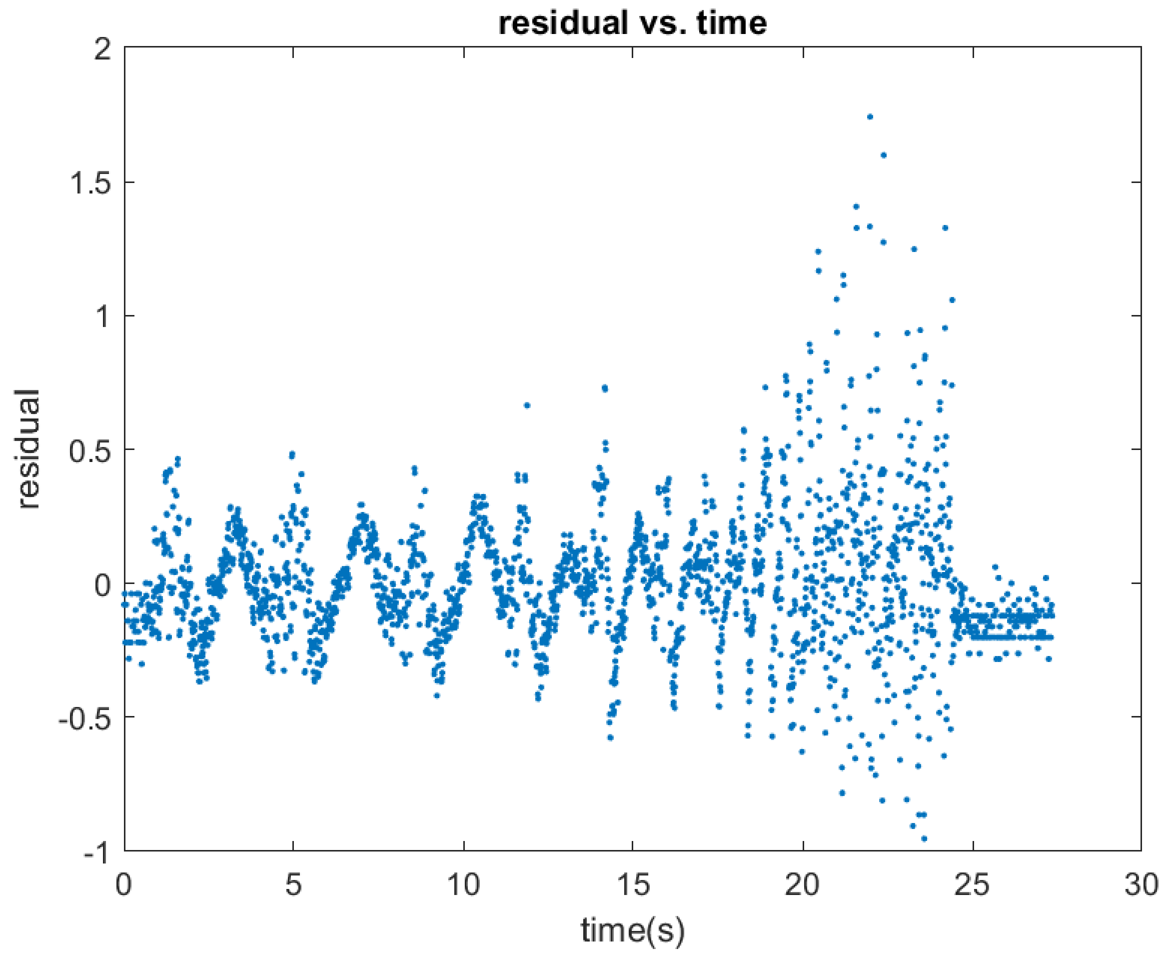
The coefficient of determination for the frequency sweep is quite good. Whereas, the coefficient of determination for the step input is horrible. The model might not be applicable to the step input data. The coefficient might be too small for the step input data.

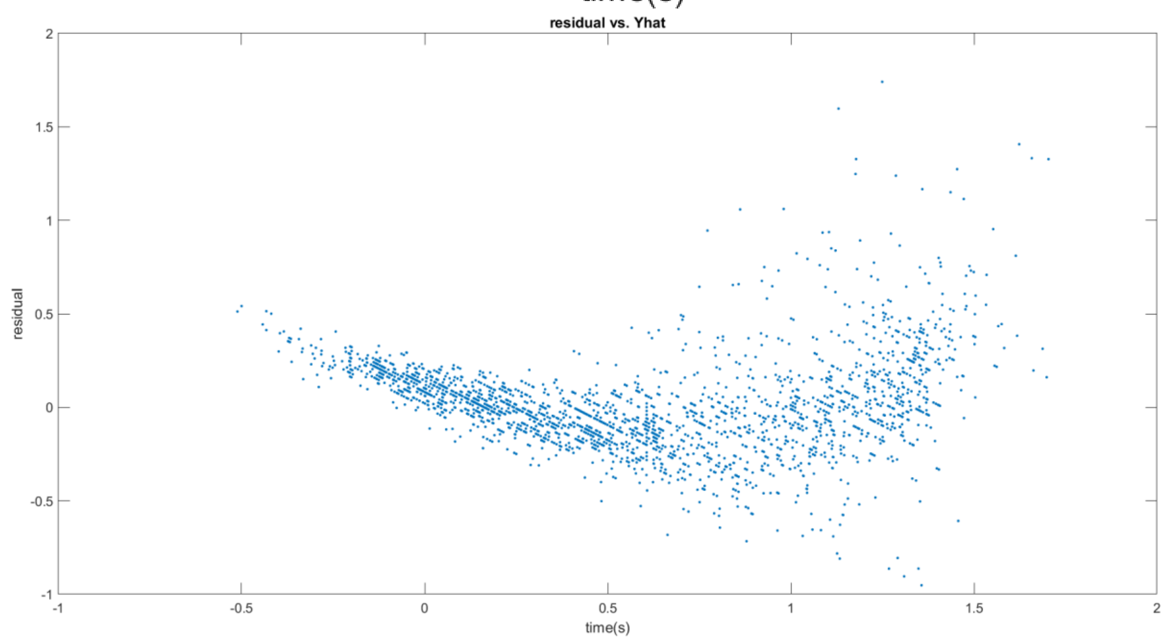
6. **Graduate Students Only:** Perform the OLS estimation using the step input and predict the output from the automated frequency sweep experiment (essentially the reverse of Problem 1 and 4). Plot the estimated vs. measured thrust from the sweep. Comment on how the fit compares with the frequency sweep estimation and the step response verification.

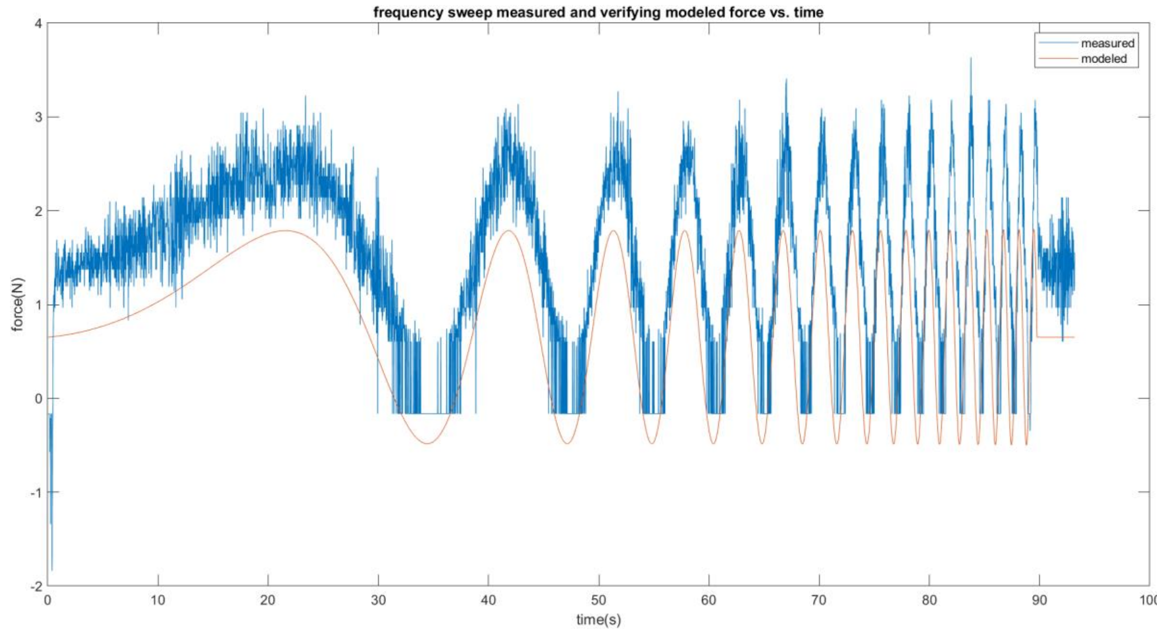



```
The model is: Y_hat = T_hat(1) * thr + T_hat(2) * deriv(thr,.01) + T_hat(3)

T =

  3×4 table

    param      T_hat       T_hat_confid    percent_T_hat_confid
    _____    ________    ____________    ____________________

    {'A'}      3.7829        0.01335              0.3529
    {'B'}    -0.12889     9.8809e-05           -0.076658
    {'C'}     -5.0227        0.02973             -0.5919
```

Parameter	Estimated Value	Confidence Interval	Confidence Interval Percent
A	3.78	±.013	±35.3%
B	-0.12	±.00009	±7.7%
C	-5.02	±0.03	±59.2%


residual vs. time
residual
time(s)
2
1.5
1
0.5
0
-0.5
-1
0
5
10
15
20
25
30


residual vs. Yhat
residual
time(s)
2
1.5
1
0.5
0
-0.5
-1
-1
-0.5
0
0.5
1
1.5
2




```
The step input R squared value is:

R_sq =

    0.7895

The frequency sweep R squared value is:

R_sq2 =

   -0.5210
```

The coefficient of determination for the step input is quite good. Whereas, the coefficient of determination for the frequency sweep is horrible. The model might not be applicable to the frequency sweep data. The coefficient might be too large for the step input data.

<u>Code</u>

```
% Alex Dowell
% ME 494 HW 2 #1-#5
% F = A * thr + B *thr' + C
load MotorData.mat

l = load_cell;
thr = throttle;
```

```
t = time;
x = [thr, deriv(thr,.01), ones(9315,1)];
T_hat =(x'*x)\x'*l;
Y_hat = T_hat(1) * thr + T_hat(2) * deriv(thr,.01) + T_hat(3);

disp('The R squared value is:')
v = l - Y_hat;
R_sq = (T_hat'*x'*l - length(l)*mean(l)^2) / (l'*l - length(l) * mean(l)^2);
R_sq
figure(1)
plot(t,l,t,Y_hat)
title('measured and modeled force vs. time')
xlabel('time(s)')
ylabel('force(N)')
legend('measured','modeled')

% #2 %
disp('and the estimated parameters are:')
T_hat
v = (l - Y_hat);
s_sq = sum(v.^2)/(length(v) -length(T_hat));
T_hat_confid = 2 * sqrt(s_sq) * diag((x'*x)^-1);
disp('and the confidence intervals are:')
T_hat_confid
percent_T_hat_confid = (T_hat_confid./T_hat)*100;
disp('and the confidence intervals percent are:')
percent_T_hat_confid
param = {'A', 'B', 'C'};
param = param'
disp('The model is: Y_hat = T_hat(1) * thr + T_hat(2) * deriv(thr,.01) + T_hat(3)')
T = table(param,T_hat,T_hat_confid, percent_T_hat_confid)

% #3 %
R = l - Y_hat;
figure(2)
plot(t,R,'.')
title('residual vs. time')
xlabel('time(s)')
ylabel('residual')
figure(3)
histogram(R)
figure(4)
plot(Y_hat, R, '.')
title('residual vs. Yhat')
```

```
xlabel('Yhat(N)')
ylabel('residual')
% #4 %
load MotorData_Verify.mat
l2 = load_cell;
thr2 = throttle;
t2 = time;
Y_hat_verify = T_hat(1) * thr2 + T_hat(2) * deriv(thr2,.01) + T_hat(3);
figure(5)
plot(t2,l2,t2,Y_hat_verify)
title('measured and verifying modeled force vs. time')
xlabel('time(s)')
ylabel('force(N)')
legend('measured','modeled')

% #5 %
disp('The frequency sweep R squared value is:')
v = l - Y_hat;
R_sq = (T_hat'*x'*l - length(l)*mean(l)^2) / (l'*l - length(l) * mean(l)^2);
R_sq
disp('The step input R squared value is:')
v2 = l2 - Y_hat_verify;
x2 = [thr2, deriv(thr2,.01), ones(2736,1)];
R_sq2 = (T_hat'*x2'*l2 - length(l2)*mean(l2)^2) / (l2'*l2 - length(l2) * mean(l2)^2);
R_sq2

% Alex Dowell
% ME 494 HW 2 #6
% F = A * thr + B *thr' + C
% #6
load MotorData_Verify.mat

l = load_cell;
thr = throttle;
t = time;
x = [thr, deriv(thr,.01), ones(2736,1)];
T_hat =(x'*x)\x'*l;
Y_hat = T_hat(1) * thr + T_hat(2) * deriv(thr,.01) + T_hat(3);

figure(1)
plot(t,l,t,Y_hat)
title('step input measured and modeled force vs. time')
xlabel('time(s)')
ylabel('force(N)')
```

```
legend('measured','modeled')

% #6_2 %
disp('and the estimated parameters are:')
T_hat
v = (l - Y_hat);
s_sq = sum(v.^2)/(length(v) -length(T_hat));
T_hat_confid = 2 * sqrt(s_sq) * diag((x'*x)^-1);
disp('and the confidence intervals are:')
T_hat_confid
percent_T_hat_confid = (T_hat_confid./T_hat)*100*100;
disp('and the confidence intervals percent are:')
percent_T_hat_confid
param = {'A', 'B', 'C'};
param = param';
disp('The model is: Y_hat = T_hat(1) * thr + T_hat(2) * deriv(thr,.01) + T_hat(3)')
T = table(param,T_hat,T_hat_confid, percent_T_hat_confid)

% #6_3 %
R = l - Y_hat;
figure(2)
plot(t,R,'.')
title('residual vs. time')
xlabel('time(s)')
ylabel('residual')
figure(3)
histogram(R)
figure(4)
plot(Y_hat,R,'.')
title('residual vs. Yhat')
xlabel('time(s)')
ylabel('residual')

% #6_4 %
load MotorData.mat
l2 = load_cell;
thr2 = throttle;
t2 = time;
Y_hat_verify = T_hat(1) * thr2 + T_hat(2) * deriv(thr2,.01) + T_hat(3);
figure(5)
plot(t2,l2,t2,Y_hat_verify)
title('frequency sweep measured and verifying modeled force vs. time')
xlabel('time(s)')
ylabel('force(N)')
```

```
legend('measured','modeled')

% #6_5 %
disp('The step input R squared value is:')
v = l - Y_hat;
R_sq = (T_hat'*x'*l - length(l)*mean(l)^2) / (l'*l - length(l) * mean(l)^2);
R_sq
disp('The frequency sweep R squared value is:')
v2 = l2 - Y_hat_verify;
x2 = [thr2, deriv(thr2,.01), ones(9315,1)];
R_sq2 = (T_hat'*x2'*l2 - length(l2)*mean(l2)^2) / (l2'*l2 - length(l2) * mean(l2)^2);
R_sq2
```