Yaw Thrust from Pitch - Parameter Estimation

There is a reaction torque acting on the yaw axis from the pitch rotor. This lab shows how to find the thrust gain parameter that captures this effect.

Concept Review

In the 2 DOF configuration, the motion of the yaw is affected by both rotors. The yaw/rear rotor applies a direct thrust about the yaw axis but the pitch/front rotor generates a torque on the yaw axis as well. This can be respresented by the following equation of motion (EOM):

The Aero 2 yaw axis model can be represented by the equation of motion

$$J_y\ddot{\psi} + D_y\dot{\psi} = K_{yy}D_tV_y + K_{yp}D_tV_p$$

where ψ is the yaw angle, J_y is the equivalent moment of inertia acting about the yaw axis, D_y is the viscous damping, K_{yy} is the yaw thrust force gain from the yaw rotor, K_{yp} is the thurst force gain acting on the yaw axis from the pitch rotor, D_t is the distance from the pivot point to the propeller, and V_y is the voltage applied to the rear/yaw rotor motor.

The pitch thrust, inertia, damping, and stiffness were identified in the 2 *DOF Parameter Estimation: Yaw* lab. Because we are only applying a voltage to the pitch/front rotor, $V_y = 0$, and the pitch-axis is locked the EOM becomes

$$J_y\ddot{\psi} + D_y\dot{\psi} = K_{yp}D_tV_p$$

Solving for the thrust gain parameter

$$K_{yp} = \frac{J_y\ddot{\psi} + D_y\psi}{D_tV_p}$$

We can find the thrust gain from the measure yaw rate and derived acceleration

Lab Procedure

Apply a step to front/pitch motor and measure yaw response. Load existing data or run the Simuilnk model in QUARC to take new measurements.

Setup

1. Make sure the Aero 2 has been tested as instructed in the Quick Start Guide.
2. Launch MATLAB and browse to the working directory that includes the Simulink models for this lab.
3. Configure the Aero 2 in the 2 DOF Helicopter configuration:
4. **Unlock** the pitch axis and **lock** the yaw axis.
5. Rear rotor 1 is **vertical** and front rotor 0 is **horizontal**.
6. Mount weight on each rotor.
7. Connect the USB cable to your PC/laptop.
8. Connect the power and turn the power switch ON. The Aero base LED should be red.

Lab 1: Get Open-Loop Response

The open-loop response can be obtained by running the `q_aero2_yaw_from_pitch_step` Simulink model shown in Figure 1 with QUARC.

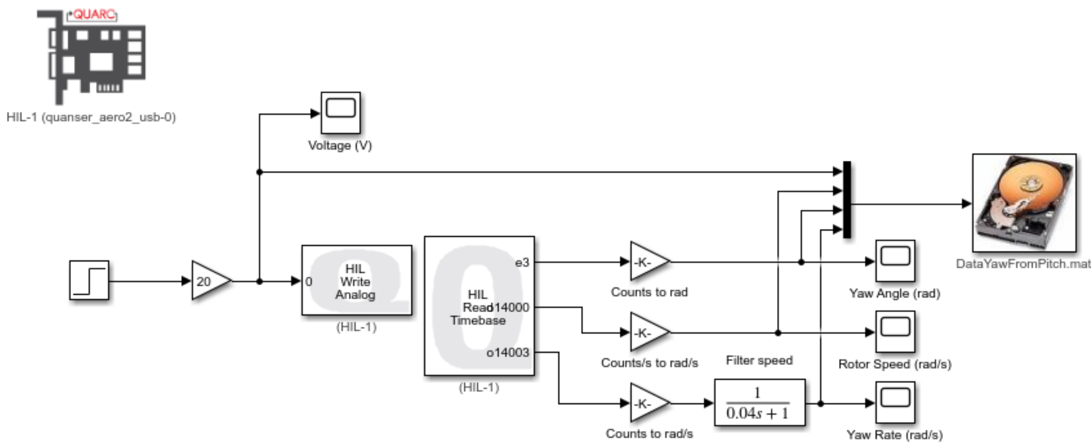


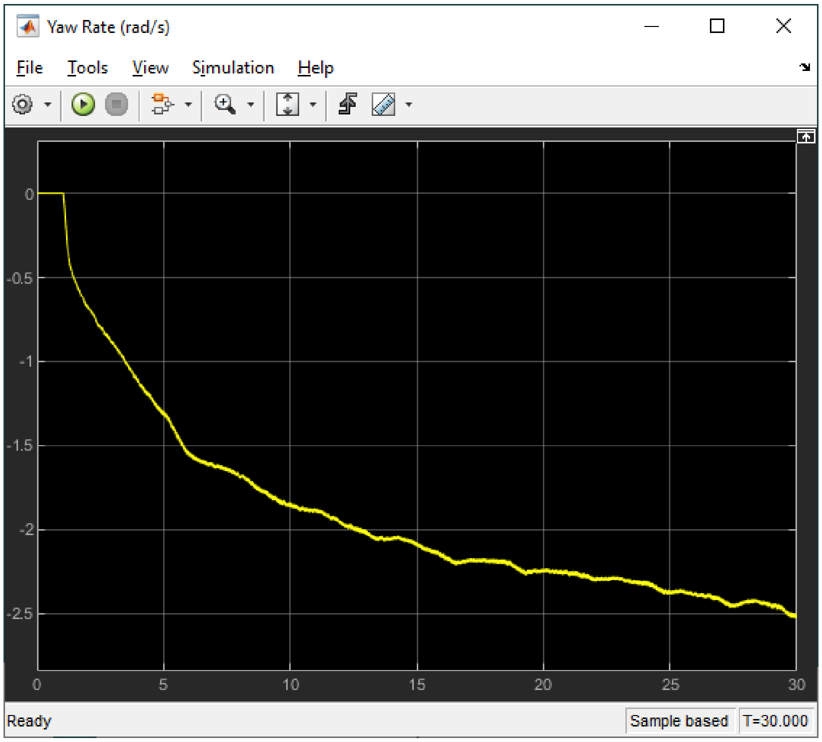
Figure 1 - Simulink model used with QUARC to apply a voltage to the front rotor and measure the yaw rate and angle.

The Simulink model uses the `HIL Write Analog` and `HIL Read Timebase` blocks from the *QUARC Targets* library to apply a voltage to the front pitch rotor and measure the corresponding pitch angle response. The response is saved into a MATLAB *.mat files using the `To Host File` block. This can then be used to plot the results and perform the parameter estimation analysis.

Build and run the following Simulink model in QUARC by clicking on the *Monitor & Tune* button.

```
% Load Simulink model
open("q_aero2_yaw_from_pitch_step.slx");
```

Figure 2 shows the yaw rate response and applied voltage in the scopes.



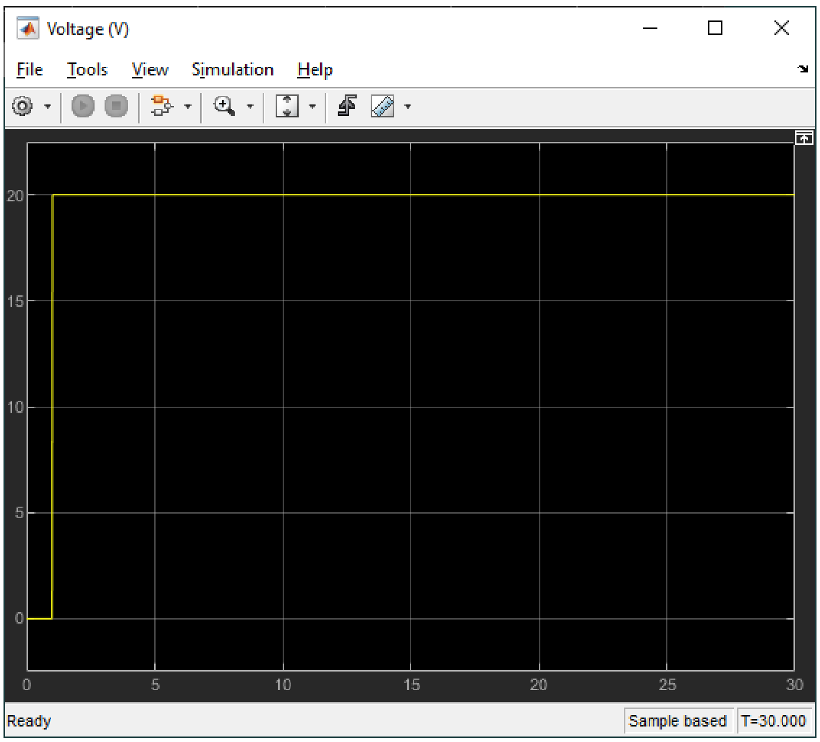
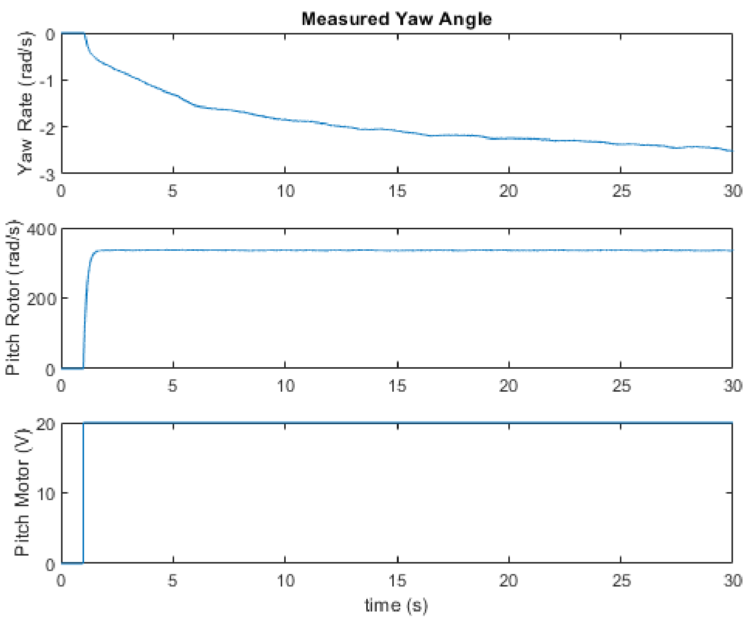


Figure 2 - Yaw angle rate response from applying a step to the front pitch rotor.

Plot measured response

```
% Load measured data from past run
load('DataYawFromPitch.mat');
% store in variables
t = YawFromPitch(1,:); % time (s)
Vp = YawFromPitch(2,:); % pitch/front motor voltage (V)
```

```
wm_p= YawFromPitch(3,:); % pitch/front rotor speed (rad/s)
psi = YawFromPitch(4,:); % yaw angle (rad)
psi_dot = YawFromPitch(5,:); % yaw angular rate (rad/s)
%
subplot(3,1,1);
plot(t,psi_dot);
title('Measured Yaw Angle');
ylabel('Yaw Rate (rad/s)');
subplot(3,1,2);
plot(t,wm_p);
ylabel('Pitch Rotor (rad/s)');
subplot(3,1,3);
plot(t,Vp);
ylabel('Pitch Motor (V)');
xlabel('time (s)');
```



Lab 2: Find Thrust Gain

Load the AERO 2 Parameters

```
aero2_parameters;
```

Load stiffness, damping, and thrust parameter values that you found in the parameter estimation lab.

```
% Thrust (N-m/V)
Kyy = 0.00614;
% Damping (N-m/V)
Dy = 0.00214;
```

Find the yaw from pitch thrust force gain.

```
% Sampling interval of controller (s)
h = 0.002;
```

```
% Yaw acceleration from measured rate (rad/s^2)
psi_ddot = diff(psi_dot)/h;
% size of acceleration response
iif = length(psi_ddot);
% Thrust gain (N/V)
Kyp = ( Jy*psi_ddot + Dy*psi_dot(1:iif) ) / ( Dt*Vp(1:iif) )
```

```
Kyp = -0.0019
```

The measured cross-thrust acting on the yaw-axis from the pitch/front rotor is

$K_{yp} = -0.00185$ N/m