Measuring Bicopter Motor Thrust and Power With Test Stands

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Measuring Bicopter Motor Thrust and Power Overview

1. Thrust-stand Calibration
2. Thrust – Pulse Width Correlation
3. Moment Stand Calibration
4. Electrical Power Correlation
5. Power Efficiency Analysis

6. Comparison With Manufacture Specifications

7. Updated Bicopter Simulink Model

8. Updated Simulink Pulse-width Profile

9. New and Old Model Output Comparison

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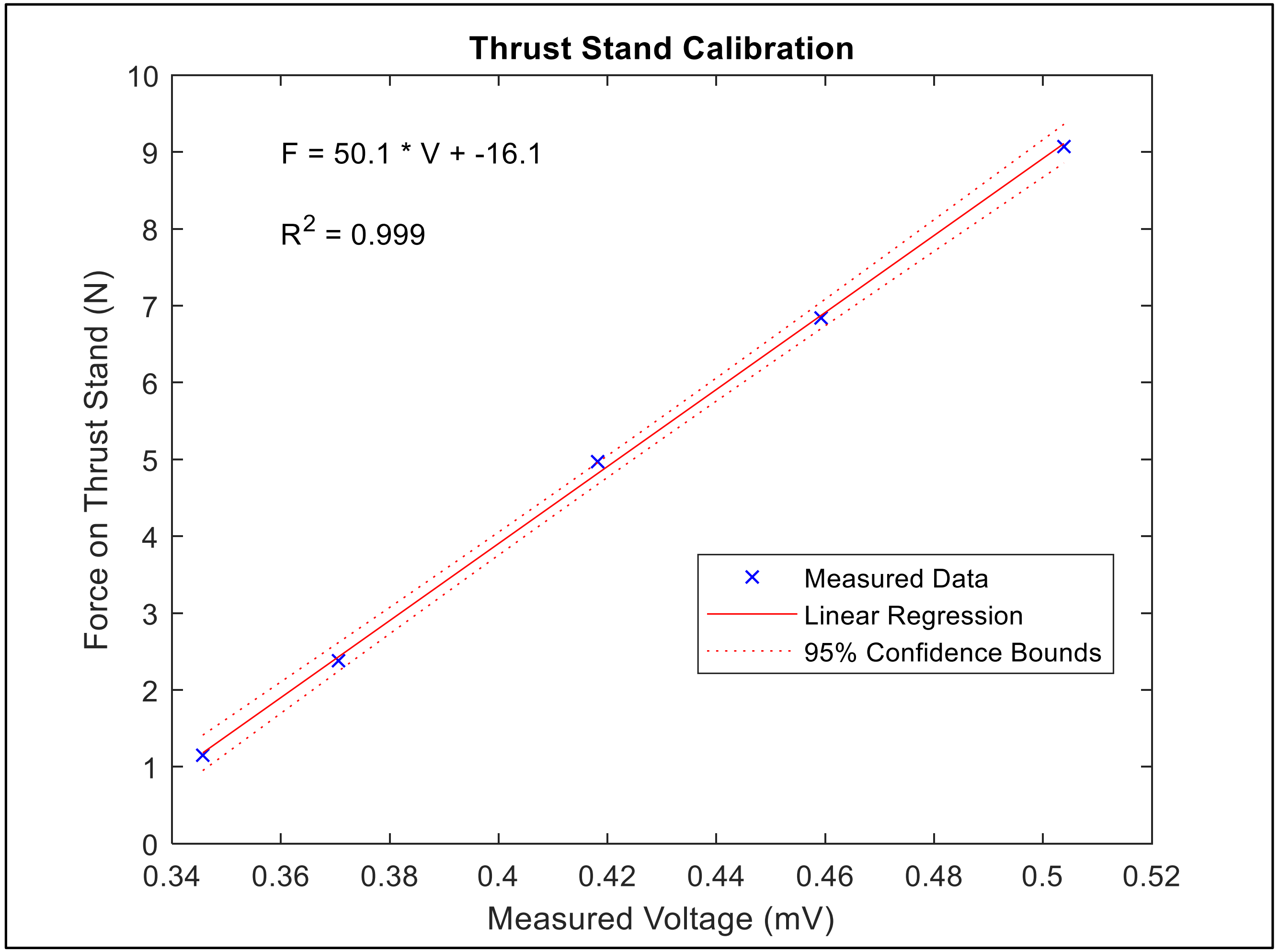
1. Thrust Stand Calibration



Procedure

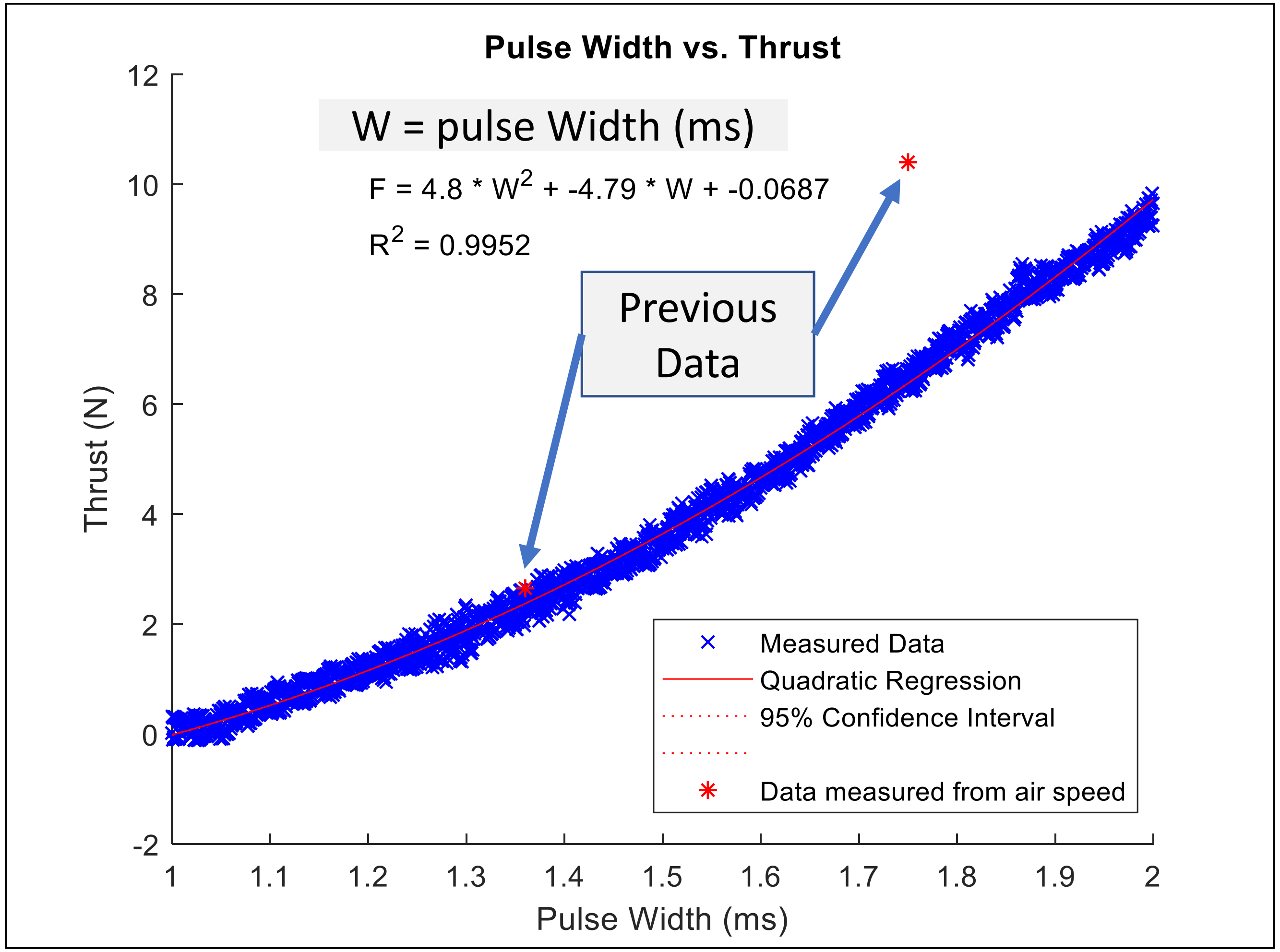
1. Mass attached to thrust stand parallel to the measurement direction
2. Voltage of load cell and mass recorded
3. Propeller from 1 to 2 ms pulse widths over 20 seconds.

Analysis

Calibration of the stand was done by taking the recorded data, importing it into MATLAB and doing a linear regression of the data. All of the recorded data falls within the 95% error bounds.

The fit is very good with a high R^2 value, and it is clear that the correlation is highly linear with low error. The approximate root-mean-square error of 0.0996 Newtons, with all the measured data within the 95% error bounds.

2. Thrust – Pulse Width Correlation



Summary

The thrust was determined using the voltage from the loadcell on the thrust stand, and then using the thrust stand correlation function determined previously. This thrust was then least-squares fit quadratically to get a function that correlates the 1 to 2 ms pulse width to thrust. One of the values measured previously using conservation of momentum is among the data measured, but the other is much higher than the thrust measured with the thrust stand.

The thrust data was correlated with the a quadratic curve using the least-squares method of fit. It was fit with a high R^2 value, with a resulting root-mean-square error of the measured data of approximately 0.995 Newtons.

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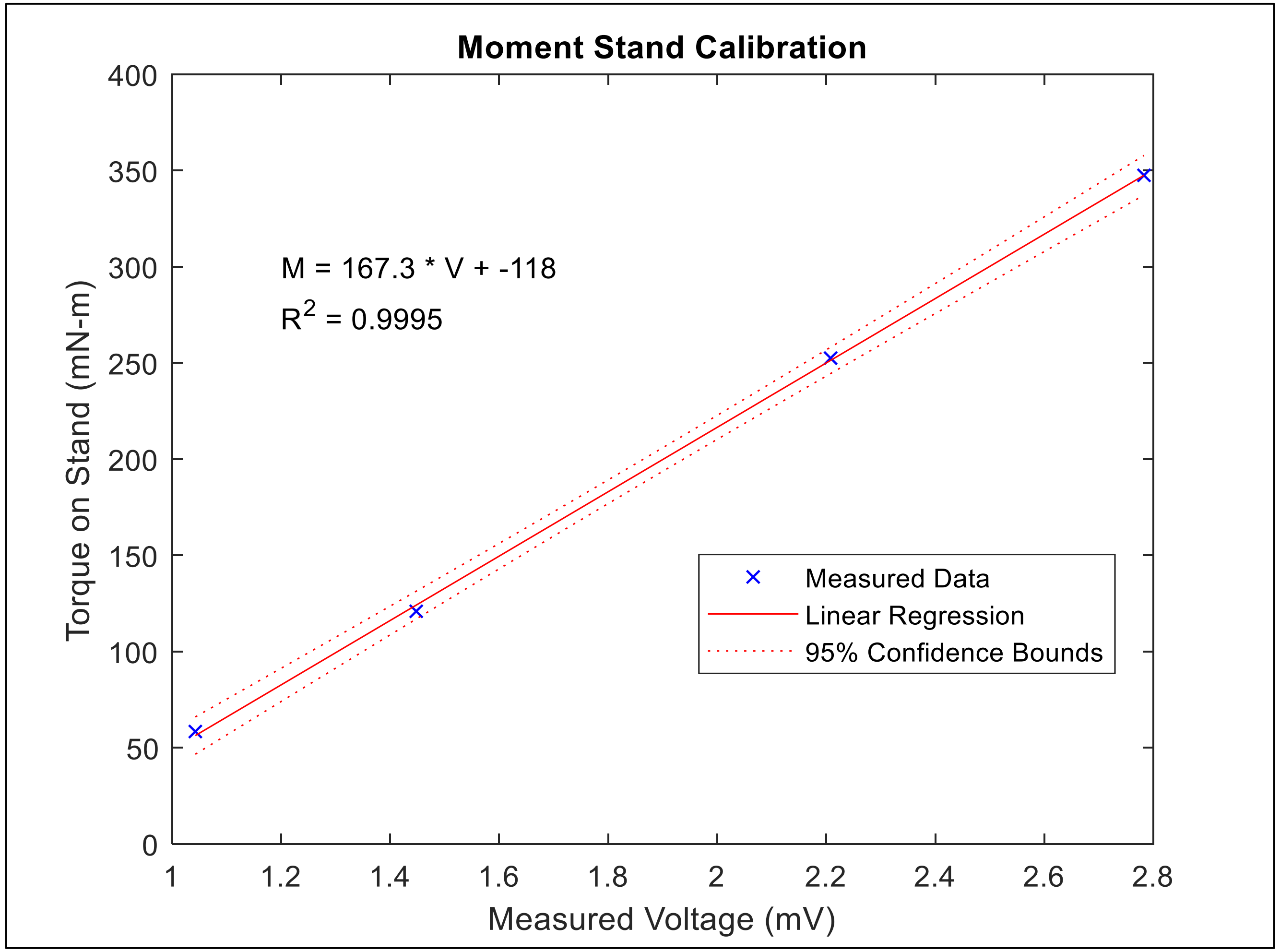
3. Moment Stand Calibration



Procedure

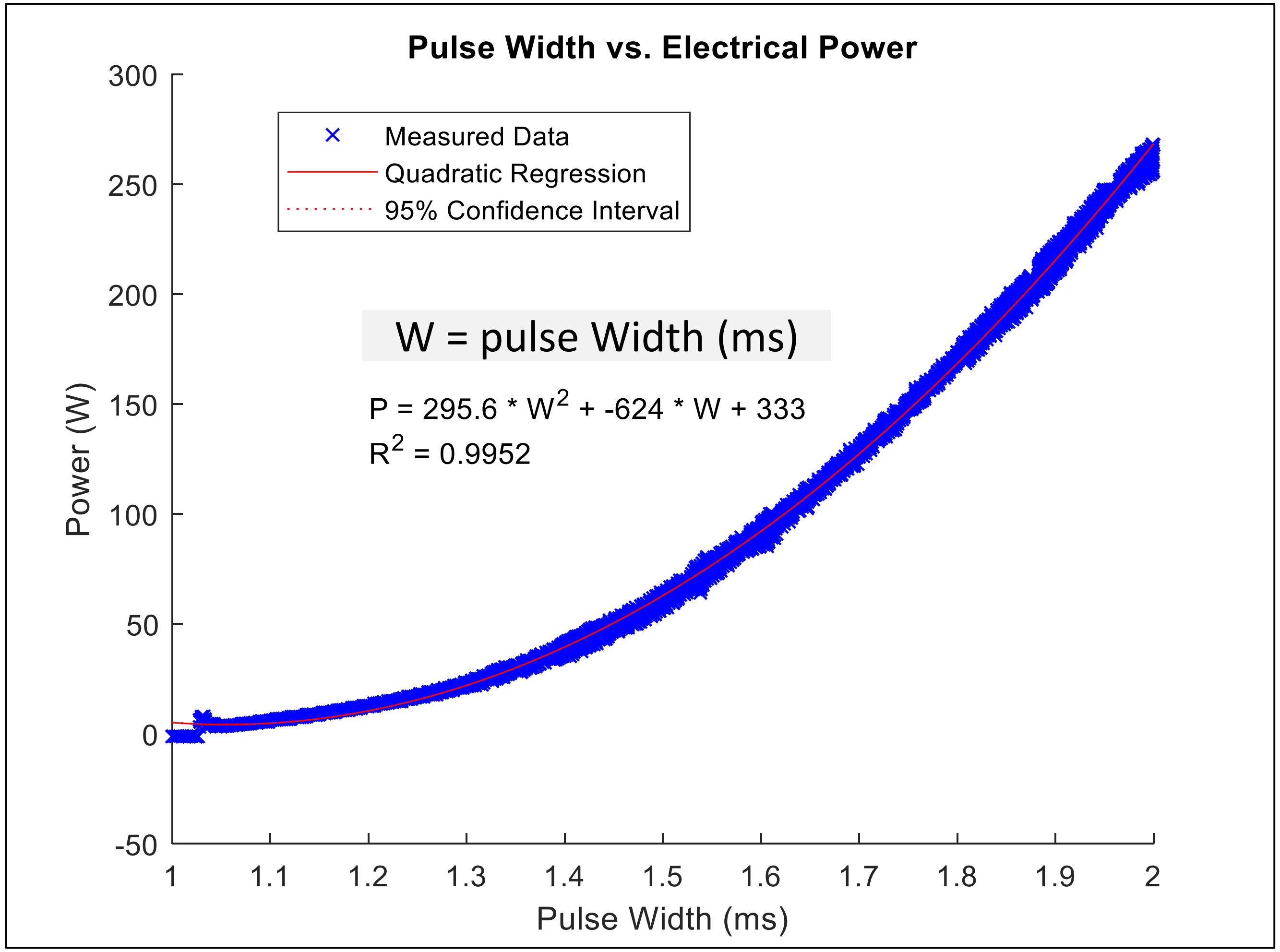
1. Mass attached to moment stand parallel to the measurement direction
2. Voltage of load cell and mass recorded
3. Propeller from 1 to 2 ms pulse widths over 20 seconds.

Analysis

Calibration of the stand was done by taking the recorded data, importing it into MATLAB and doing a linear regression of the data. All of the recorded data falls within the 95% error bounds.

The fit is very good with a high R^2 value, and it is clear that the correlation is highly linear with low error. The approximate root-mean-square error of the measured data about the fit line is 2.84 mN-m.

4. Electrical Power Correlation

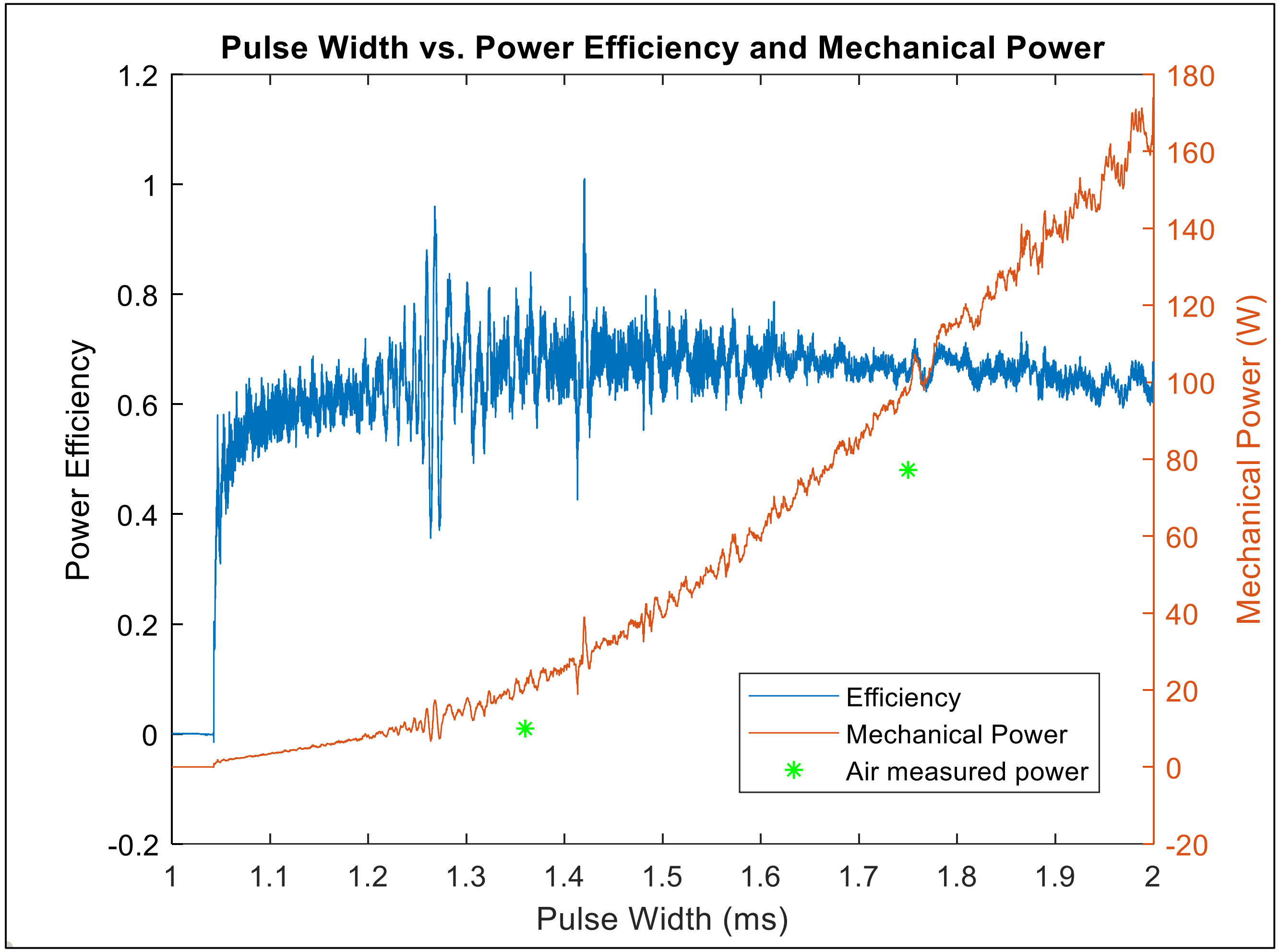


Analysis

The electrical power of the propeller was measured using an inductive current clamp on the power lines, and an analog to digital converter on the DAQ system to capture the voltage. Using these two values, there were multiplied together according to Ohm's Law to get the electrical power consumed by the system.

Afterwards the data was analyzed and the power correlated with the pulse width to get the electrical power as a function of the pulse width. This was done in MATLAB using the least-squares method. The R2 value of the fit is high, and the root-mean-square error of the data about the fit is 2.46 Watts, and with the order this data is on this error is acceptable.

5. Power Efficiency Analysis



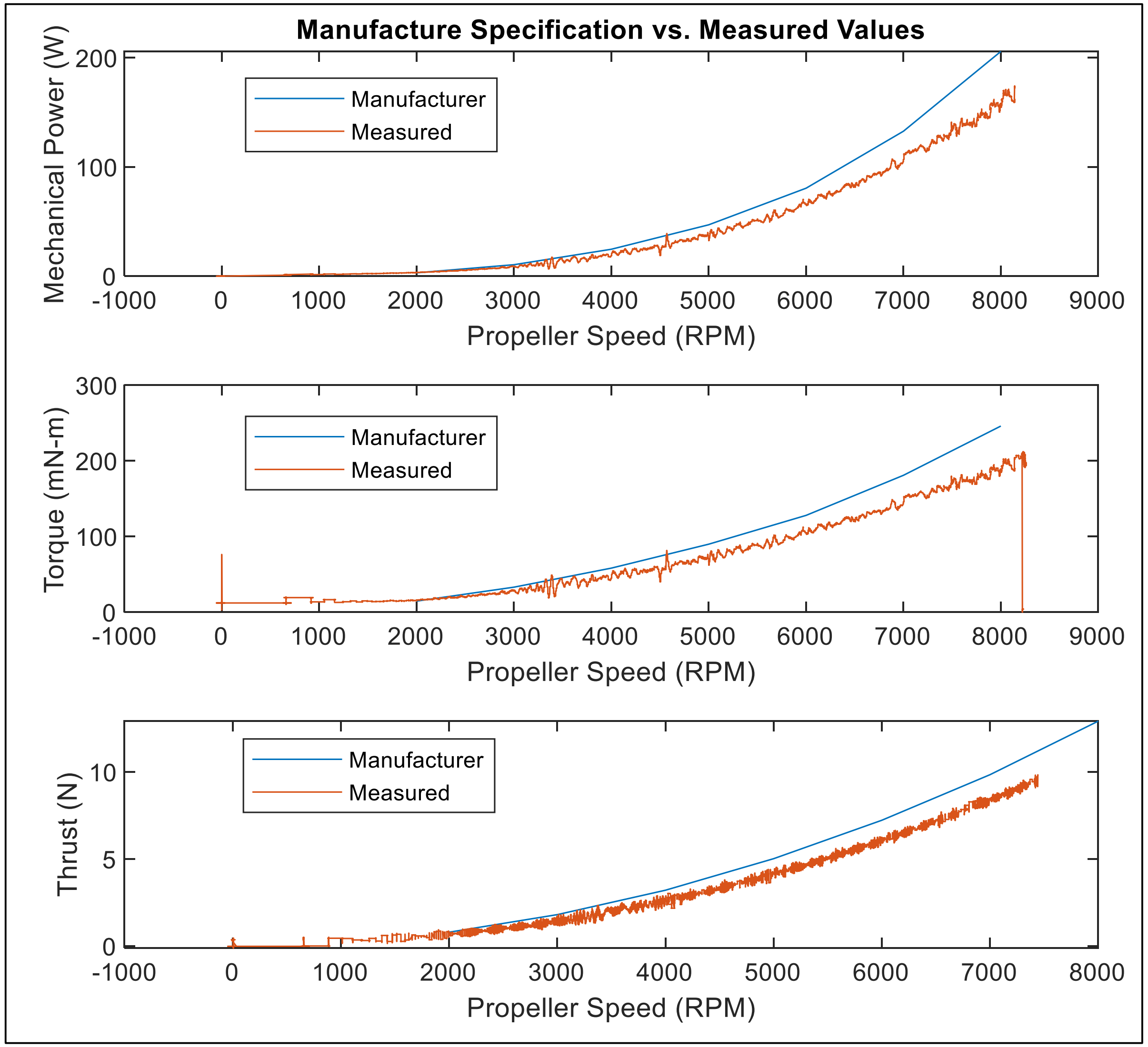
Analysis

After calculating the electrical power previously, the efficiency of the system could then be determined. This was done by multiplying the propeller's rotational speed with the moment that the moment stand measured with its loadcell. The efficiency was then calculated by dividing the input, the electrical power, by the output, the mechanical power.

The mechanical power compared to the power measured previously using the conversation of energy principles is not quite in line, the data is not within the error of either of the data points by about 10W each.

As seen on the plot to the left, the efficient is relatively stable throughout the pulse-width sweep. It ranges from around 45% on the low side to around 65% barring discontinuities.

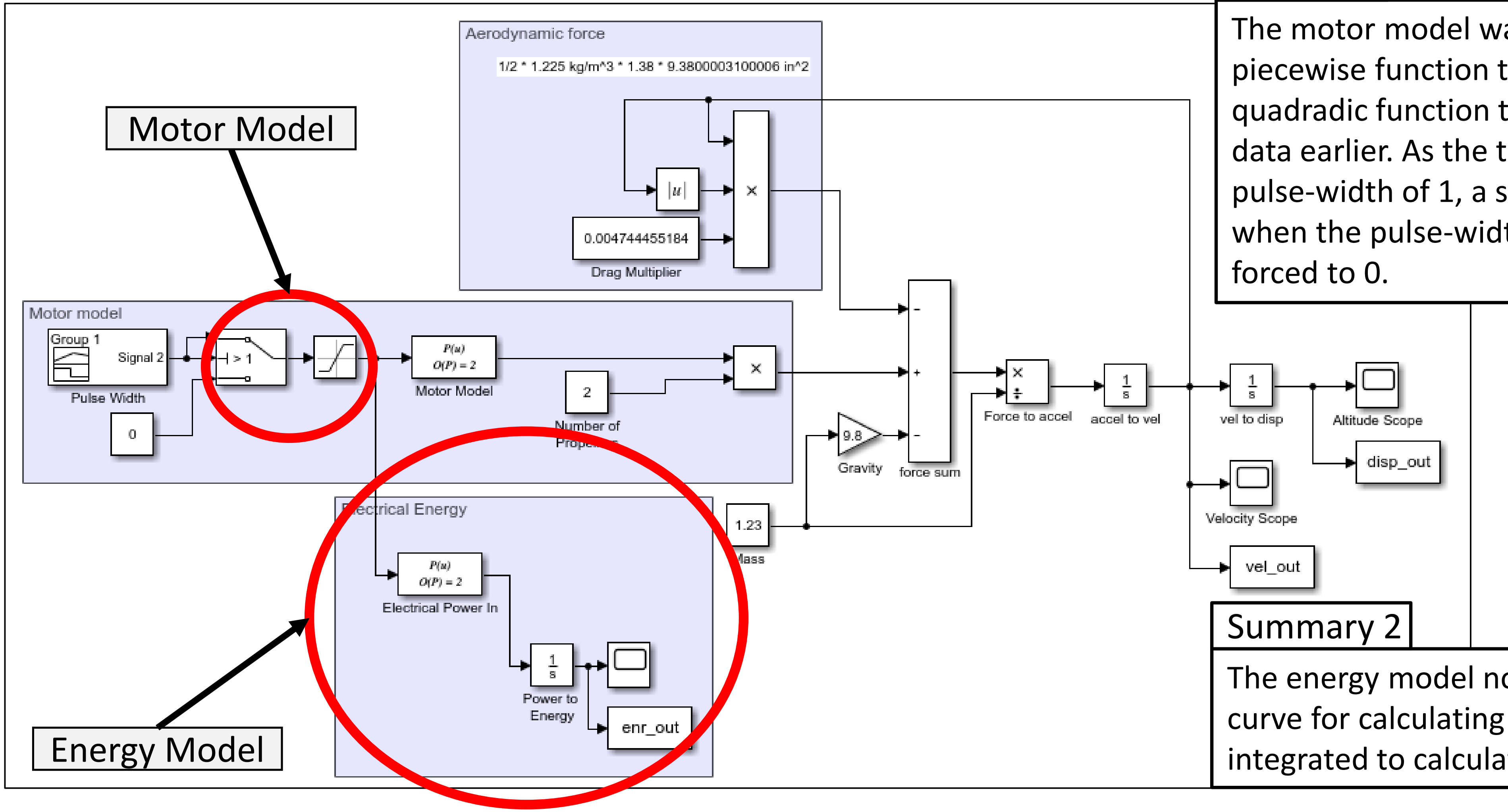
6. Comparison With Manufacture Specifications



Summary

Comparing the manufacturer reported specification with the measured values from this test, the reported values are higher than the measured values consistently. This make sense as the manufacture would want to report the best values they have recorded to get people to buy their product. At the same time the error is not extremely significant, and while it is not within the error bars of the calibration done in this test it may be within the error of the values measured by the manufacturer.

7. Updated Bicopter Simulink Model



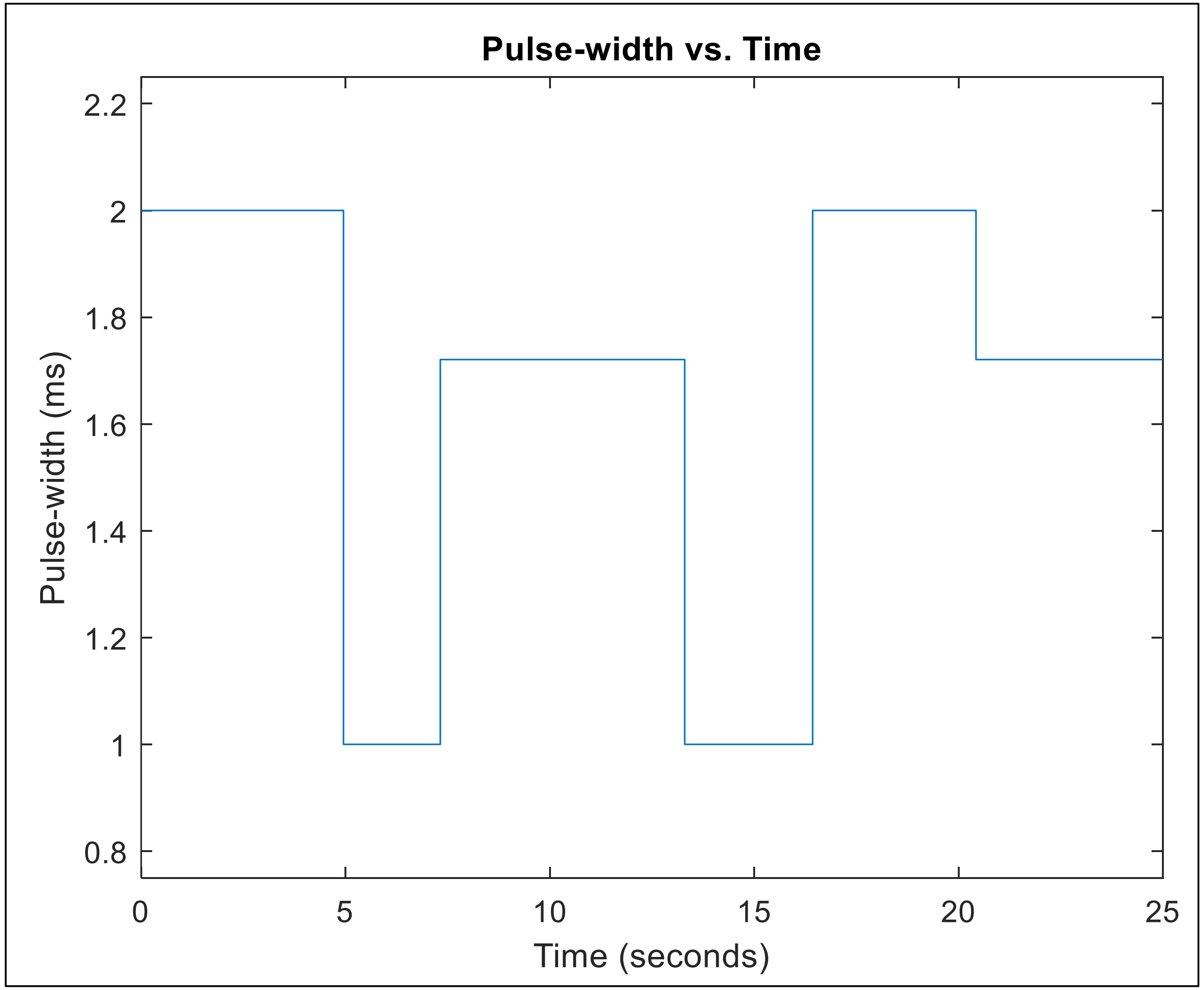
Summary

The motor model was updated from the linear piecewise function that it was before, to the quadradic function that was fit to the measured data earlier. As the thrust needs to be zero below a pulse-width of 1, a switch was also added so that when the pulse-width is below one the thrust is forced to 0.

Summary 2

The energy model now also uses a quadradic fit curve for calculating power, then the power is integrated to calculate the electrical energy used.

8. Updated Simulink Pulse-width Profile



Summary

The pulse-width profile this time around is extremely similar to the previous one, the only differences being:

- The hover pulse-width is slightly large (~0.04)
- The times shift a bit between the state transitions

Other than that it still follows the three-state profile of on, off, and hover to minimize the time of manuvers.

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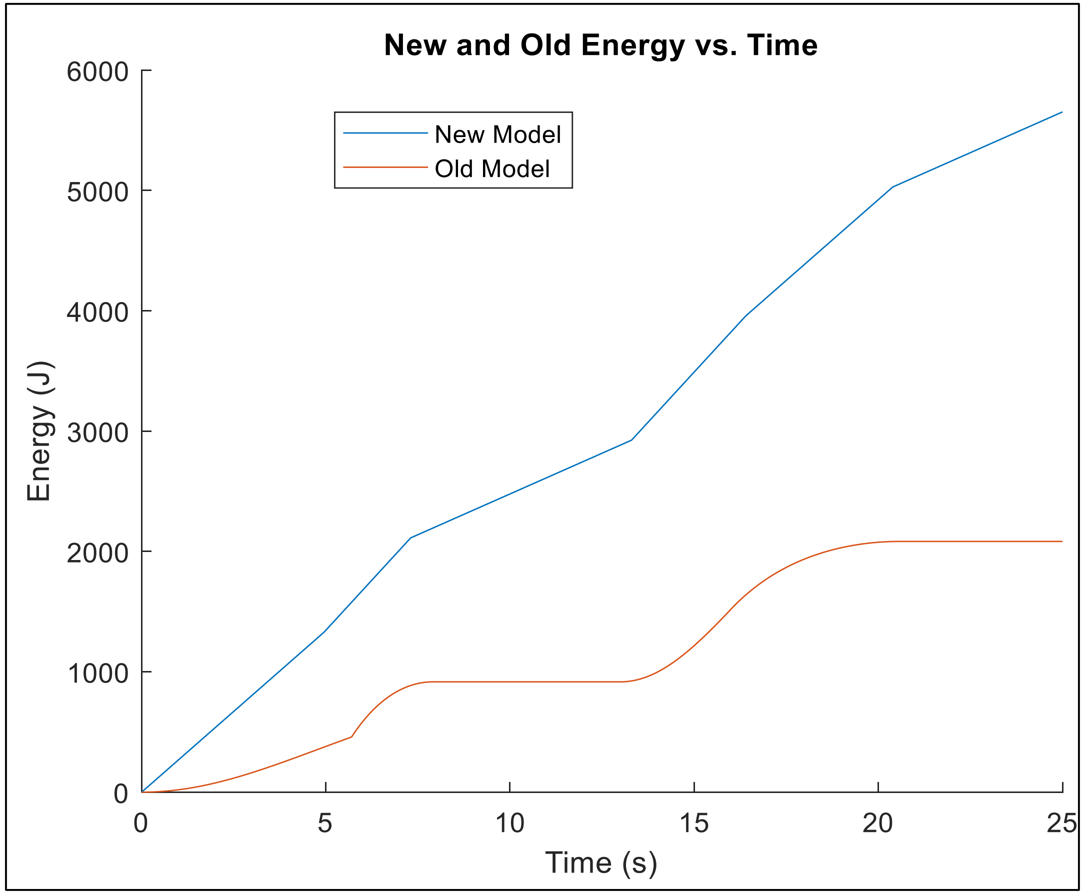
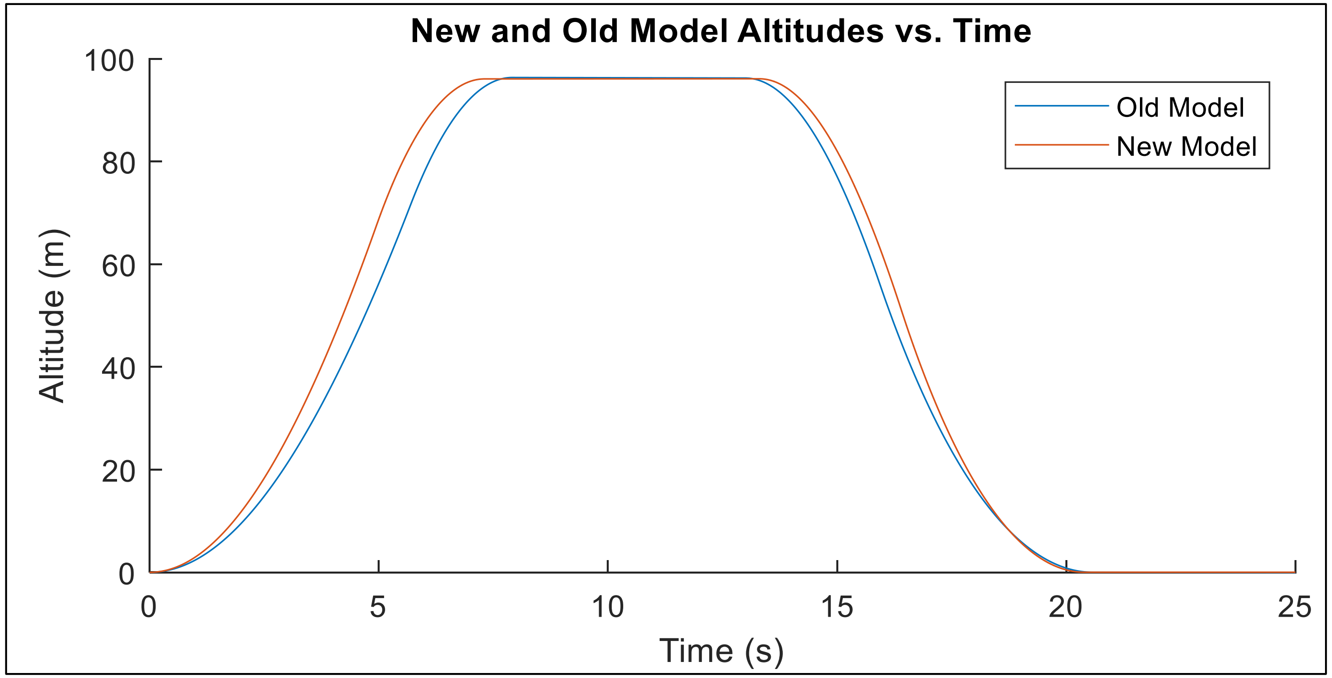
9. New and Old Model Output Comparison

Summary

Comparing the altitudes shown below, the are relatively the same, which makes sense are when I tuned the model I used the same semi-bang-bang method as before. For the enrgy the new model consumes much more energy compared to the old model, most likely due to it consuming power while idling and well and the efficiency number used previously not being compleley accurate.





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