Experimental Estimation of Loaded Spindle Inertia

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***Abstract*—Previously 3D CAD models within Solidworks were used to estimate the inertia of the material spindle and carbon fiber spools. In order to verify the validity of the approximation, a simple experiment was done to approximate the inertia of the system at the output of the gearbox.**

I. Introduction

The effective inertia of the system is an extremely important quantity when sizing the motor. Approximating the inertia accurately reduces the risk of oversizing the motor and the other components in the system relevant to power delivery.

II. Inertia Estimation

Previously weighing carbon spools and creating solid models with similar geometry and uniform density was used to estimate the inertia of the spool which is the main inertial element in the system. Interpolation methods were then used to estimate the inertia for any radius that lies within the range of modelled values.

Another simple method is to use a hollow cylinder geometry with uniform density to approximate the inertia.

$$I_{cyl} = \frac{1}{2}MR^2 \tag{1}$$

Assuming the carbon portion is uniform density and takes on the form of a hollow cylinder, the carbon inertia can then be approximated with the following method.

$$I_{cyl} = \frac{1}{2}MR^2 \tag{2}$$

$$I_{carbon} = \frac{1}{2}\rho l \pi r^4 - \frac{1}{2}\rho l \pi r_0^4 \tag{3}$$

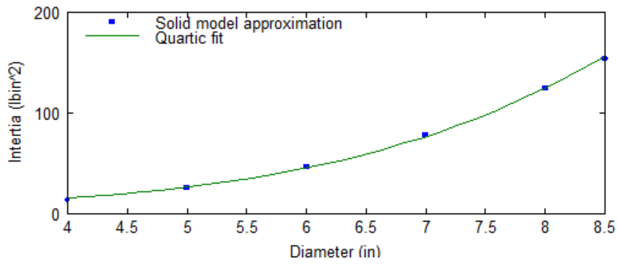
The spindle, cardboard roll and other inertia elements are then lumped as a single constant I_0. Since the second term in the carbon fiber inertia is constant this will also be lumped into I_0.

$$I_{effective}(r) = I_0 + \frac{1}{2}\rho l \pi r^4 \tag{4}$$

The quartic relationship with radius in (4) means that the inertia of the system will decrease rapidly as material is payed out. Notably, the plastic backing wrapping around the take up is neglected for simplicity.

III. Inertia Calculation Comparison

Using data provided by Kyle Jeffries, a curve fit was performed on the inertia approximations. The fit agrees with the current approximation method well and therefore will be used in the controller implementation.



IV. Proportional Gain Re-tuning

In order to maintain the same overall disturbance rejection a simple condition is to be maintained.

$$K_p r_s = C_0 \tag{5}$$

Where C_0 is some constant

Therefore, suppose that initially the gain is set to its maximum when the inertia of the spool is largest using (6).

$$K_p = \frac{2T_m}{v_o I_e} \tag{6}$$

Then, C_0 can be calculated and an explicit formula used for K_p can be obtained. This ensures that the closed loop performance is the same throughout all radii. Thus, the update equation in the control loop is given in (7).

$$K_p = C_0 / r_s \tag{7}$$