

## Gearbox Evaluation

There are multiple causes of power loss through a gearbox but only two are significant enough to account for. The two significant losses are load and velocity dependent. Therefore, it is necessary to measure the mechanical input and output power versus load torque and output angular velocity. Calculating the gearbox efficiency is trivial and is governed by the below equation.

$$\eta_{GB} = \frac{P_{output}}{P_{input}} \quad \text{Eq. (1)}$$

Provided by the University of Idaho was a General Electric dynamometer. This dynamometer consisted of an electric generator leveraged by a scale, figure (1). Electromechanical losses in dynamometers of this type are widely considered negligible. However, frictional losses from bearings and other mechanical features are significant and need to be accounted for. Other system losses to account for are from the power supply, motor driver (MD), and the electric motor itself.

The electrical power required by the MD and power supply cannot be modelled, but required electrical power to the motor can be modelled using Eq(1) and Eq(2). Electrical power can be calculated knowing the DC voltage and current to the MD.

$$P_{avg} = V_{rms}I_{rms} \quad \text{Eq. (2)}$$

Armature voltage and current at steady state are DC/rms values. Using the above equation, the electrical power into the system becomes

$$PE_{avg}(\tau, \omega) = a\tau^2 + b\tau\omega + c\tau + d\omega \quad \text{Eq. (3)}$$

where the coefficients  $a, b, c,$  and  $d$  can be experimentally determined using 2<sup>nd</sup> order polynomial regression analysis.

Using the quadratic formula, the output torque of the motor can be calculated in terms of electrical power to the motor and speed of the motor.

$$\tau(PE_{avg}, \omega) = -(b\omega + c) + \frac{\sqrt{(b\omega + c)^2 - 4ac(d\omega - PE_{avg})}}{2a} \quad \text{Eq. (4)}$$

Multiplying by the angular velocity of the motor yields mechanical output power of the motor in terms of speed and electrical power into the MD.

$$P_{ME,in}(PE_{avg}, \omega) = \omega * \tau(PE_{avg}, \omega) \quad \text{Eq. (5)}$$

Using this equation, the electrical losses of the MD and the power supply are bypassed and accounted for.

The mechanical output of the gearbox can then be calculated with the below equation.

$$P_{ME,out} = \tau_{out}\omega_{out} + P_{Loss,Dyno}(\omega_{out}) \quad \text{Eq. (6)}$$

Where the power loss through the dyno will have to be experimentally determined.

## Equipment

1. General Electric Dynamometer
2. 0-12lbf Scale
3. MeanWell Power Supply, 48V 20A
4. Anaheim Automation MDC151-050601 Motor Driver
5. RadioShack 22-178 multimeter
6. Tachometer (Any type will work)



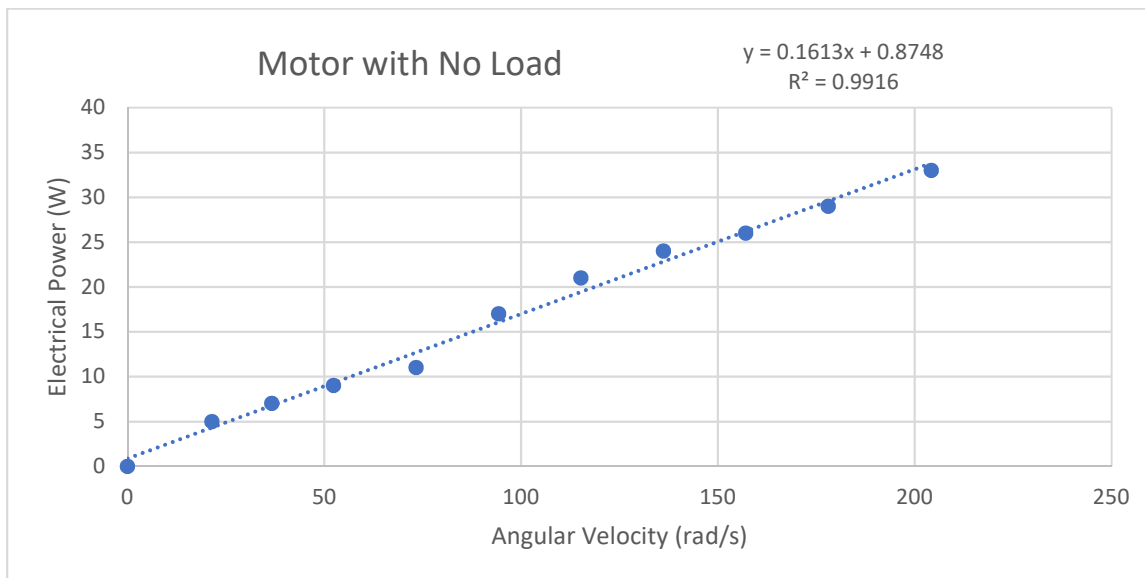
*Fig. 1. Dynamometer on the left, Asynchronous motor on right and scale is above dyno. This is the initial set up of the dyno before disconnecting the current motor and mounting the TG5153 frame.*

## Procedure

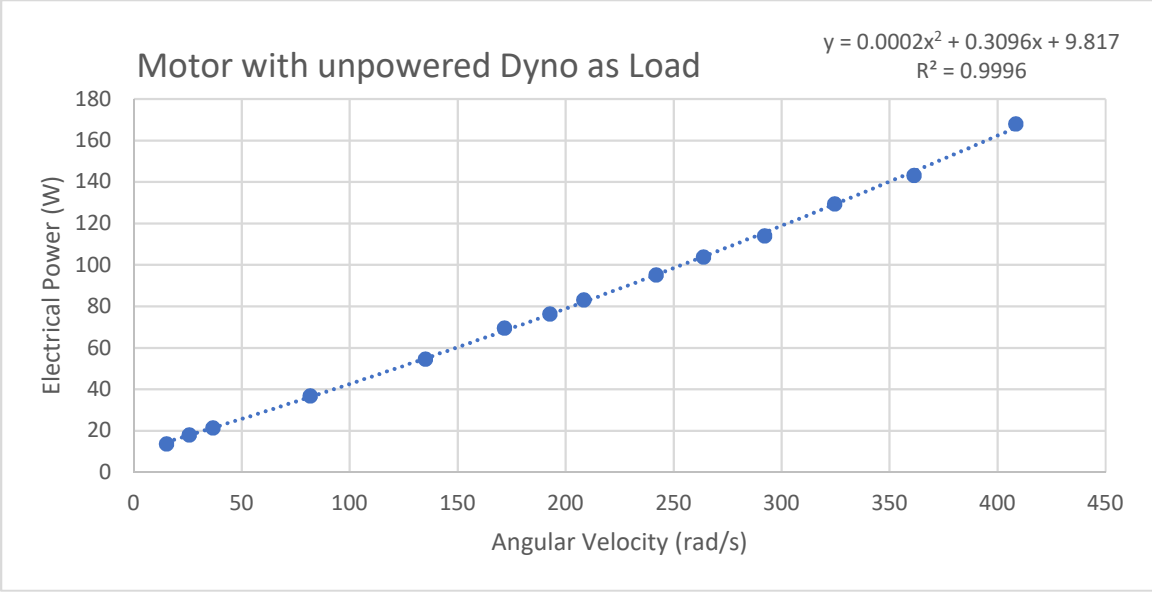
To compensate for all losses, three experimental runs were executed. For the first run, the bare motor was run at varying speeds and the electrical power was recorded. Second run, the dynamometer was powered down and the motor was coupled to the dyno. The second step allowed for calculation of frictional loss of the dyno. Third run, the dyno was powered to provide mechanical resistance and the electrical power to the motor was recorded verses constant torque and varied speed. The third run was used to produce a mechanical output map verses electrical power and motor speed. Testing the gearbox involved the same process as testing in the third run.

1. Run motor with no load. Vary motor speed and record electrical power.
2. Run motor on unpowered Dyno. Vary motor speed and record electrical power.
3. Run motor on powered Dyno. Hold a constant torque, vary the RPM of the motor and repeat with an incremented torque. Record electrical power.
4. Repeat step 3 but with motor mounted to gearbox and output shaft coupled to Dyno.

## Results



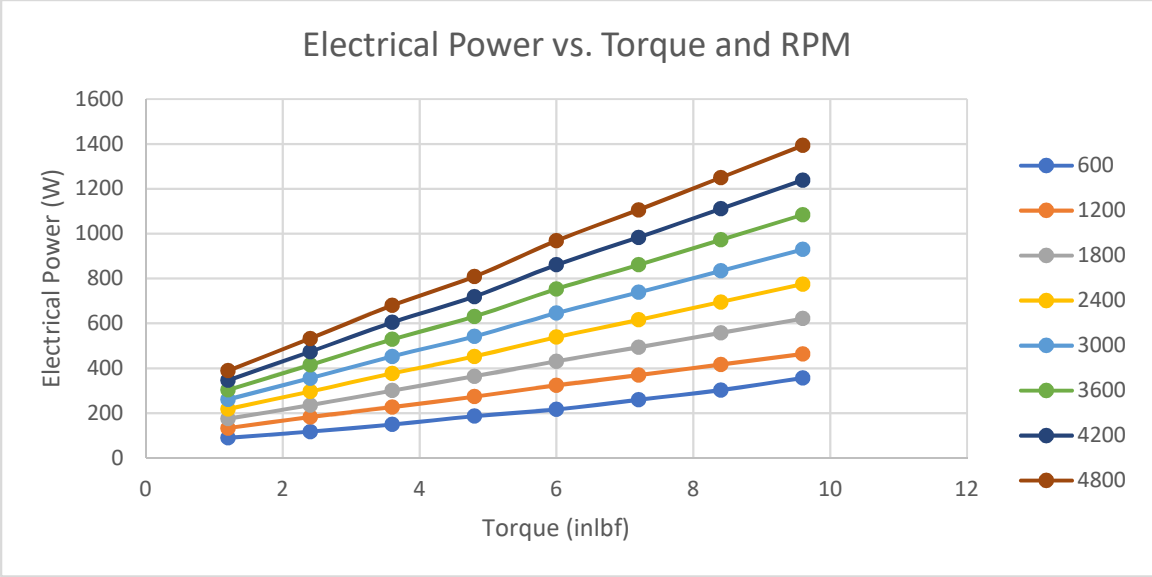
**Fig. 2.** Motor did not have an applied load for this run.



**Fig. 3.** Dynamometer was powered down and motor was coupled to the Dyno.

Using the results from figures (2) and (3) the power loss through the dyno can be calculated by subtracting the difference in electrical power draw.

$$P_{Loss,Dyno}(\omega) = 0.0002\omega^2 + 0.1483\omega + 8.9442 \quad \text{Eq. (7)}$$



**Fig. 4.** Dynamometer was powered, and motor was coupled to Dyno.

**Table 1.**

<b>a</b>	<b>b</b>	<b>c</b>	<b>d</b>
5.3611	1.57	171.8	0.5856

After using MatLab to perform a regression analysis, the constants in Table 1 were found. With these constants, Eq. 3 and 4 are satisfied and the full efficiency analysis can be performed. Using Excel and extrapolating the extremes, the efficiency was approximated to be  $\approx 80\%$ . Please refer to Appendix () for raw data.