

Power Generation Feasibility:

Power generated by a propeller is a function of the inlet and outlet velocities of the airstream, the area circumscribed by the propeller, and aerodynamic constants. The derivation is fundamentally a reformulation of Bernoulli's equation:

$$F = \frac{1}{2} \rho A (v_e^2 - v_i^2)$$

While this is a simple equation, downstream velocity is difficult to obtain and ultimately must come from experiment if it is to be reliably known. Other models exist for this purpose, which are formed by derivation from base principles and then exercises of curve fitting. Research suggests that models for static thrust are sufficiently accurate that we can utilize them for design purposes. It is important to note, however, that the force is dependent on the incoming velocity. The dynamic thrust equations found are not as reliable. Derivations are located [here](#) and the methods are critiqued [here](#).

Static:

$$F = 1.225 \frac{\pi(0.0254 \cdot d)^2}{4} \left(RPM_{prop} \cdot 0.0254 \cdot pitch \cdot \frac{1min}{60sec} \right)^2 \left(\frac{d}{3.29546 \cdot pitch} \right)^{1.5}$$

Dynamic Thrust Equation

F = thrust (N), d = prop diam. (in.), RPM = prop rotations/min., pitch = prop pitch (in.), V₀ = propeller forward airspeed (m/s)

Expanded Form:

$$F = 1.225 \frac{\pi(0.0254 \cdot d)^2}{4} \left[\left(RPM_{prop} \cdot 0.0254 \cdot pitch \cdot \frac{1min}{60sec} \right)^2 - \left(RPM_{prop} \cdot 0.0254 \cdot pitch \cdot \frac{1min}{60sec} \right) V_0 \right] \left(\frac{d}{3.29546 \cdot pitch} \right)^{1.5}$$

Simplified Form:

$$F = 4.392399 \times 10^{-8} \cdot RPM \frac{d^{3.5}}{\sqrt{pitch}} (4.23333 \times 10^{-4} \cdot RPM \cdot pitch - V_0)$$

Gabriel Staples, 2013. <http://electricaircraftguy.blogspot.com/>

Note: these equations are only valid in English units. Coefficients will need to be recalculated if conversion to SI is desired.

In order to streamline the calculations a spreadsheet exists. It is located on edge.

The accuracy of the dynamic thrust equation is questionable. We will be verifying our results by comparison with charts provided at the APC (a propeller manufacturer) [website](#). These values are calculated using an undisclosed CFD suite. A portion of a typical chart is reproduced below:

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20x10                      (20x10.dat)                      12/22/14

===== PERFORMANCE DATA (versus advance ratio and MPH) =====

DEFINITIONS:
J=V/nD (advance ratio)
Ct=T/(rho * n**2 * D**4) (thrust coef.)
Cp=P/(rho * n**3 * D**5) (power coef.)
Pe=Ct*J/Cp (efficiency)
V (model speed in MPH)

PROP RPM =      1000

V          J          Pe          Ct          Cp          PWR          Torque          Thrust
(mph)     (Adv Ratio)
0.0        0.00      0.0000      0.0794      0.0311      0.008        0.504          0.405
0.5        0.03      0.0655      0.0792      0.0316      0.008        0.513          0.404
1.0        0.05      0.1284      0.0789      0.0321      0.008        0.521          0.402
1.5        0.08      0.1886      0.0785      0.0326      0.008        0.529          0.400
2.0        0.10      0.2461      0.0779      0.0331      0.009        0.537          0.397
2.5        0.13      0.3008      0.0772      0.0336      0.009        0.544          0.394
3.0        0.16      0.3526      0.0764      0.0340      0.009        0.551          0.389
3.5        0.18      0.4016      0.0753      0.0343      0.009        0.556          0.384
4.0        0.21      0.4476      0.0740      0.0345      0.009        0.561          0.377
4.5        0.24      0.4907      0.0724      0.0347      0.009        0.563          0.369
5.0        0.26      0.5307      0.0705      0.0347      0.009        0.564          0.360
5.4        0.29      0.5675      0.0684      0.0346      0.009        0.562          0.349
5.9        0.31      0.6010      0.0657      0.0343      0.009        0.556          0.335
6.4        0.34      0.6310      0.0624      0.0336      0.009        0.545          0.318
6.9        0.37      0.6568      0.0591      0.0329      0.008        0.534          0.301
7.4        0.39      0.6791      0.0557      0.0322      0.008        0.522          0.284
7.9        0.42      0.6975      0.0522      0.0313      0.008        0.508          0.266
8.4        0.44      0.7124      0.0487      0.0304      0.008        0.493          0.248
8.9        0.47      0.7239      0.0451      0.0293      0.008        0.475          0.230
9.4        0.50      0.7325      0.0414      0.0280      0.007        0.455          0.211
9.9        0.52      0.7383      0.0376      0.0266      0.007        0.432          0.192
10.4       0.55      0.7420      0.0337      0.0249      0.006        0.404          0.172
10.9       0.58      0.7433      0.0297      0.0230      0.006        0.373          0.151
11.4       0.60      0.7408      0.0257      0.0208      0.005        0.338          0.131
11.9       0.63      0.7337      0.0215      0.0184      0.005        0.299          0.110
12.4       0.65      0.7167      0.0173      0.0158      0.004        0.256          0.088

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These efforts, paired with benchmarking, seem to suggest that we will develop about 8-10lbs of thrust with most propeller configurations. We may be able to produce up to 15 lbs under ideal situations with our motor but we are still in the process of evaluating those claims.