What Size Motor Do I Need?

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When you build a model that is designed to be powered by an electric motor, most of the time the kit manufacturer already gives recommended motor sizes. This is especially true if the kit manufacturer is large company like Horizon or Great Planes, who also sells electric power systems. For other kit manufacturers, or for models that were originally designed for glow engines, picking the right motor can be a bit challenging. In today's blog post, I am going to go through the steps of selecting the correct Motor, ESC, Battery and prop for an aircraft.

To begin this process, you need to know a few things about the model. Most important are the weight of the model, the type of model, the desired flight speed and the desired flight duration. With these specifications, a power system can easily be chosen which will provide the required power.

There are a few rules of thumb that I like to go by when selecting a power system for a model. The first ones are for Glow to Electric conversions. For a decent, ball-bearing ABC type 2-stroke glow engine, each cubic inch of displacement is roughly equal to 2000 watts of electrical input power. To get the required wattage motor for a model, you simply multiply the engine displacement by 2000, and you get the required number of watts.

For example, if you have a plane that is designed to fly with a .45 to .50 size 2-stroke engine, .45 x 2000 equals 900 watts, and .50 x 2000 equals 1000 watts. This means that you would be looking for a motor that consumes somewhere between 900 and 1000 watts of electrical power. Likewise, a .25 size engine equals about 500 watts, a .60 size engine equals around 1200 watts and a .90 size engine equals about 1800 watts of electrical power.

When considering a 4-stroke glow engine, the conversion factor is around 1500 watts per cubic inch. Base on this, a .45 4-stroke engine would need 675 watts, and a .60 size 4-stroke would require 900 watts of power from an electric motor.

The new rule of thumb is based on the performance requirements on a "watts per pound" basis, depending on the type of aircraft. Different types of aircraft have different power requirements, based on the type of aircraft, wing loading, drag and other considerations. Based on this, you can get the following "categories" of models, and the amount of power required.

Motor Gliders: (50 to 60 watts per pound) These types of planes are essentially gliders with a motor assist to get them up to altitude without the need for a winch or high-start line. The lightweight structures of these models have very low wing loadings, and do not require much power to pull them through the air. In this category, a 2-pound glider would need 100 to 120 watts of power.

Trainers: (70 to 80 watts per pound) These types of models have moderate wing loadings, with high-lift flat bottom airfoils, and spend most of their time flying at around ½ throttle. This much power would give you the equivalent of a plane like a Midwest Aerostar 40 or Great Planes PT-40 trainer powered with a basic ringed .40 glow engine. In this category, a 5-pound trainer would need around 400 watts of power.

Sport Models: (100 to 120 watts per pound) These types of planes are more advanced acrobatic models such as the famous Ugly Stick, Great Planes Sportster or SIG Cougar. A 6 pound Ugly Stick type model with a good .45 ABC glow engine would have this level of power, and would take about 700 watts of electrical power to get similar performance.

Pattern and Warbird Models: (140 to 160 watts per pound) While these are different classes of aircraft, they both have similar power requirements. Pattern models need good power for clean up-lines and the ability to carry speed through large loops. Warbird models typically have higher wing loadings that other similar sized models, especially if a lot of scale details and retracts are included. An 8-pound airplane with a piped .60 size engine would have this type of power level.

3-D Aerobatic Planes: (200 to 220 watts per pound) These types of planes typically fly with a 2 to 1 thrust to weight ratio, and have the ability to hang on the prop in a hover at 50% throttle. From a glow engine perspective, this would be like having a 3-pound sport model with a hot .45 size engine.

Pylon Racers: (250 watts per pound and up) Going fast takes a lot of power, and pylon racing is all about going fast. Since pylon races typically last for less than 2 minutes, you can use a lot of power quickly, and only carry enough battery to get the job done.

There are other things to consider when selecting an electric motor for a model, such as battery capacity and propeller size. Because electric motors tend to put out more torque than equivalent size glow engines, they tend to spin larger props at a lower speed that their glow counterparts. However, there are cases where the design of the model limits the prop size, and this is when getting the right Kv version of a motor comes into play.

Many electric motor manufacturers try to "Make it easy" for people coming over from glow to electric by naming their motor with "equivalent" size numbers. For example, a company might call their motor a Power .40 to signify that it makes power similar to a .40 glow engine. The problem with this naming convention is that the electric motor will only perform like a .40 glow engine on a specific size battery, with 2 or 3 specific size props.

Electric motors are essentially "Constant Speed Machines", and try to spin at the same RPM regardless of load. Because of this trait, the prop is the most important part of an electrical power system, as it "pulls" the power out of the motor. If you take a motor that is rated as a .40 glow equivalent, and run it on a 4-cell Li-Po battery, it may take a 12×8 prop to pull 800 watts of power because of the motors Kv value. Most people that fly .40 size glow engines are used to putting a 10×6 size prop on their engines, and if you put a 10×6 prop on the "Power .40" electric motor, it will most likely only make about 400 watts of power, and act like a .20 size glow engine. This would cause horrible performance and make the pilot think that the electric motor is defective, since it makes so little power.

On the other end of the spectrum, if a prop that is too large is used, the motor will make a lot more power, but the motor will pull excessive current doing it. Unfortunately, when this happens, the motor typically does this for some time, giving the pilot a false sense of security that everything is OK, when in fact, the motor is slowly being cooked to death. This is why it is so critical that a modeler have a watt-meter, and test the actual current draw of their model to make sure that they do not exceed the max current rating of the motor, battery or ESC.

When choosing an electric power system, it is important to make sure that every component is properly matched to the others. In the following example, we will walk through the step by step process for selecting a power system for a model. Let us assume that we have a 5-pound trike geared sport-pattern model, that was originally designed for a .35 to .40 glow engine, and can take a maximum prop size on 11 inches and still maintain ground clearance.

If you use the "2000 watt per cubic inch" method of selecting a motor size, you would need something between 700 and 800 watts of power. If you use the 140 to 160 watt per pound method for a pattern type model, a 5-pound plane would need between 700 and 800 watts of power. You should see that both methods end up giving you the same power requirement, and shows how both work to get you the correct size motor.

Next you would look for a motor that can produce somewhere between 700 and 800 watts of power from a prop that is 11 inches in diameter or less. Before we do that, we need to take a look at the battery size we will be using. The number of watts of power for a motor is calculated by taking the battery voltage and multiplying that by the motor current. A 3-cell battery produces 11.1 volts under load, and a 4-cell battery produces 14.8 volts under load. If we shoot for the middle of our power range, and go with 750 watts of power, running at 11.1 volts will require 750 ÷ 11.1 or 67.6 amps of current. With a 4-cell battery, 750 ÷ 14.8 give a required current of 50.7 amps.

When sizing a battery, I like to keep the Current to Voltage ratio somewhere between 3 and 5. This gives a good level of efficiency for the power system, and keeps the current in an acceptable range. In the case of the 3-cell power system 67.6 amps ÷ 11.1 volts give a ratio of 6.09, which is a bit high. For the 4-cell setup, 50.7 ÷ 14.8 equals 3.42, which is right in line with what we are looking for, so for this model, a 4-cell battery would be best. The actual capacity of the battery will be decided on a bit later, after we select a motor, and determine how long we want to fly.

At this point, the only good way to select a motor is to have prop data for the motors you are looking at. This is one area where there is a tremendous lack of information available. For the Cobra and Scorpion motors that we sell at Innov8tive Designs, virtually every motor goes through a rigorous testing phase and a comprehensive set of prop data is collected and provided to our customers. Without this data, you are really guessing at a motor to use, based on very little information.

When selecting a motor, you should always find one that has a max current rating that is 10 to 20% higher than what you actually need. This provides a bit of a cushion, and makes sure that the motor is not pushed too hard. Earlier we saw that with a 4-cell set-up, we would need to pull 50.7 amps to generate 750 watts of power. To give this cushion, a motor should be chosen that has a maximum current rating of around 60 amps or so.

Looking through some motor charts, the Cobra 3520/10 980 Kv motor looks like it will fit the bill. It has a max current rating of 60 amps, and provides good power on 11 inch props when running from a 4-cell battery. Below is a section of the prop chart for this motor that shows the prop data running on a 4-cell battery pack.

Cobra C3520/10 Motor Propeller Data					
Motor Wind 10-Turn Delta	Motor Kv 980 RPM/Volt	No-Load Current Io = 1.84 Amps @ 14v	Motor Resistance Rm = 0.025 Ohms	I Max 60 Amps	P Max (4S) 890 W
Outside Diameter 43.0 mm, 1.69 in.	Body Length 46.0 mm, 1.81 in.	Total Shaft Length 68.0 mm, 2.68 in.	Shaft Diameter 5.00 mm, 0.197 in.	Motor Weight 210 gm, 7.41 oz	

Prop Manf.	Prop Size	Input Voltage	Motor Amps	Watts Input	Prop RPM	Pitch Speed	Thrust Grams	Thrust Ounces	Thrust Eff. Grams/W
APC	9x6-E	14.8	27.19	402.4	11,965	68.0	1554	54.82	3.86
APC	9x7.5-E	14.8	41.77	618.2	11,061	78.6	1618	57.07	2.62
APC	9x9-E	14.8	45.05	666.7	10,794	92.0	1611	56.83	2.42
APC	10x5-E	14.8	33.00	488.4	11,678	55.3	1960	69.14	4.01
APC	10x6-E	14.8	36.27	536.9	11,327	64.4	1984	69.98	3.70
APC	10x7-E	14.8	42.56	629.9	11,047	73.2	2085	73.55	3.31
APC	10x10-E	14.8	57.53	851.4	10,104	95.7	1789	63.10	2.10
APC	11x5.5-E	14.8	45.51	673.5	10,864	56.6	2697	95.13	4.00
APC	11x7-E	14.8	52.40	775.5	10,420	69.1	2741	96.68	3.53
APC	11x8-E	14.8	56.81	840.8	10,160	77.0	2538	89.52	3.02
APC	11x8.5-E	14.8	60.60	896.8	9,931	79.9	2529	89.21	2.82
APC	12x6-E	14.8	56.94	842.7	10,033	57.0	3146	110.97	3.73
APC	13x4-E	14.8	50.30	744.4	10,565	40.0	3309	116.72	4.45
MAS	8x6x3	14.8	23.36	345.7	12,277	69.8	1428	50.37	4.13
MAS	9x7x3	14.8	36.29	537.0	11,400	75.6	2047	72.21	3.81
MAS	10x5x3	14.8	32.78	485.1	11,693	55.4	2132	75.20	4.39
MAS	10x7x3	14.8	45.60	674.8	10,842	71.9	2560	90.30	3.79
MAS	11x7x3	14.8	53.69	794.7	10,358	68.7	2947	103.95	3.71
MAS	11x8x3	14.8	57.51	851.2	10,111	76.6	2984	105.26	3.51
MAS	12x6x3	14.8	59.12	875.0	10,013	56.9	3309	116.72	3.78

From the chart above you can see that the APC 11×7-E prop gets us the power levels that we were looking for. Here is a list of the full throttle prop data for this combination.

Volts – 14.8

Amps – 52.4

Watts – 775

RPM – 10,420

Thrust – 96.7 ounces

Pitch Speed – 69 MPH

Now that we have a motor selected, we need to finalize the prop and select a speed controller.

The power that an electric motor produces is roughly equal to the square of the throttle percentage. At 100% throttle, they put out 100% power. At 90% throttle the power level is 0.9 x 0.9 or 81% power. At 70% throttle, the power level is about 50% of the full throttle value and at 50% throttle, the power level is about 25% of the full throttle value. Since power is equal to Voltage x Current, if the power is half, the current is also half. This means that when flying at 70% throttle, you will be able to fly twice as long as you can at full throttle, and when flying at 50% throttle, you can fly 4 times longer than you can at full throttle. This needs to be taken into consideration when you calculate battery size. If you are flying a pylon racer, where you will be flying at full throttle all the time, then you need to use the full throttle current to calculate battery size. If you are flying a sport plane, where you will be mixing it up between full throttle and partial throttle, then you can use about 2/3 of the full throttle current for calculating battery size. For a trainer model, where you spend a lot of time putzing around at half throttle, you can use half of the full throttle current for calculating battery size.

In this case, since it is a sport pattern model, we will use 2/3 of the full throttle current for calculating battery size, which is this case would be 52.4 x 2/3 or 34.93 amps. To keep the math easy, I will just round this up to 35 amps, and consider that this will be the average current draw over the course of the flight.

When calculating battery discharge rate, it is typically expressed in multiples of C. By definition, C is equal to the Amp-Hour capacity of the battery, and when a battery is discharged at a rate of 1C, it takes 1 hour, or 60 minutes to completely drain the pack. At a 2C discharge, the time gets cut in half to 30 minutes, because 60 ÷ 2 = 30. A 5C discharge rate will drain the pack in 12 minutes, and a 10C discharge will completely drain the pack in just 6 minutes.

When discharging Li-Po batteries, you NEVER want to fully discharge them. Doing so damages the internal structure of the cell and cause gassing of the electrolytes which leads to the dreaded “Battery Puffing” which signifies the beginning of the end of a Li-Po cell. It is best to only use 80% of the battery capacity for each flight, leaving 20% of the battery capacity in the pack.

Earlier we calculated that the average current draw over a flight would be around 35 amps. Next we need to decide how long we want to fly, and then select a battery to give that flight time. We should always take into account the 80% factor that was mentioned earlier to make sure that the battery we select will still have 20% of its energy left at the end of a flight. This can easily be done by basing the C-rate of discharge on 48 minutes instead of 60 minutes, since 48 is 80% of 60.

For the sake of this example, let's assume that we want to be able to fly for 7 minutes per flight, and still have 20% energy left in the pack. Normally, we would take 60 and divide that by 7 to get The C-rate of discharge, but that would drain the pack completely. By taking 48 and dividing it by 7, we get a discharge rate of 6.85C. Finally, to determine the size pack we need, you take the average current draw and divide it by the discharge rate, so 35 ÷ 6.85 = 5.11 Amp Hours. Since there are 1000 milli-Amp-Hours (mah) per Amp hour, this would mean that we need a 4-cell 5,110 mah battery pack. This would then be rounded off to the nearest standard size of a 5,000mah pack or a 5,200mah pack, depending on the brand that you are using.

So based on the motor we chose, the Cobra 3520/10, which is spinning an APC 11×7-E prop, we would need a 4-cell battery with a capacity of between 5,000 and 5,200 mah to fly for around 7 minutes per flight, leaving 20% of the battery energy in the pack at the end of the flight. All that is left to do now is select a speed controller.

Sizing a speed controller is actually pretty easy. You simply look at the maximum current capacity of the motor, which in this case is 60 amps, and select a speed controller that is equal or greater to this value. In the case of the Cobra speed controllers, there is a 6-cell 60-amp model available, and this would be a perfect fit. If the max motor current falls between two standard ESC values, always round up to the next value. For example, if your motor had a maximum current rating of 68 amps, and the choices for an ESC are 60 amps or 80 amps, you would use the 80-amp model. The ESC will never force more current into the motor if a larger one is used. The motor and prop combination determine the current draw. Having a larger ESC will simply operate cooler and more efficient.

I know that his blog post is a bit longer than usual, but I wanted to cover this subject completely from beginning to end, and explain the entire process of selecting a power system for an electric powered motor. By using this step by step method, anyone can select a power system for their model that will be guaranteed to work properly, and give the correct performance for any given model.

See you all next time!

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