<u>**motores sin escobillas**</u>

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Introducción

En mi papel como un minorista se estima que hasta tres cuartas partes de motores quemados / controladores de velocidad son el resultado de 'sobrecarga' en lugar de una fabricación defectuosa. Sin embargo creo que la industria debe compartir parte de la culpa de esto porque muy pocos 'spec' sus motores totalmente con las recomendaciones para los límites máximos de operación y recomendaciones para las hélices a diferentes voltajes de la batería. Necesitamos conocer las propiedades físicas y eléctricas de nuestro motor sin escobillas es decir, lo grande que es, lo pesado que es, lo poderoso que es y lo rápido que se va a convertir nuestra hélice a una tensión de alimentación dada.

El propósito de este artículo es para levantar algo de la mística que rodea a los motores sin escobillas y la esperanza de reducir algunos de estos fallos innecesarios en beneficio de todos los interesados.

Propiedades físicas

Fortunately most manufacturers have adopted a common code to size their motors, particularly the outrunners, but there are some exceptions such as AXI. The parameters we need to know are motor diameter (mm), Length (mm) excluding the drive shaft, weight (grams) and shaft diameter (mm). A common sizing code used on brushless motors contains the diameter and length i.e. a Thumper 3530 is 35mm in diameter and 30mm long excluding drive shaft.

Electrical Properties

This is where the confusion starts because few motors come with all the information needed to determine the optimum battery voltage and propeller selection and not all modellers have sufficient knowledge to work their way through it.

The information we need is the maximum operating voltage, current (amps) and watts (power). In addition we need to know the Kv i.e. RPM per Volt. All four parameters are very important and are inter-dependant. Change one and all the other operating parameters change as well.

Revs per Volt (Kv)

Kv is often overlooked when selecting a motor in preference to maximum wattage and battery voltage i.e. number of cells. Frequently I hear modellers complaining about the power generated by a particular motor. When questioned you discover they are using a low cell count battery with a low Kv motor i.e. a 3 cell battery and a 700 Kv motor that can handle up to 7 cells.

To calculate the propeller RPM for a motor at a given supply voltage multiply the supply voltage by 90% (0.9) of the motor Kv. i.e. Supply Voltage x Motor Kv x 0.9 = Approximate propeller RPM In the example: 11.1v x 700 x 0.9 = 6993 RPM

For Lithium Polymer (LiPo) batteries assume an operating cell voltage of 3.7v per cell at two thirds maximum continuous current loading.

i.e for a 2200mAhr 25C LiPo max continuous current =

2.2A x 25C x 2/3 = 36.6Amps

Increase the load and the cell voltage will drop. Just think of an aging car battery on a cold morning. At maximum continuous current only expect 3 volts per cell from a good battery. Batteries that are coming to the end of their life or are incorrectly labelled will be less (see article on 'C' rating and Time to charge).

Returning to Kv.

Using a 3S LiPo and a 1000Kv motor the operating RPM would be: 1000 x 11.1 x 0.9

= 9993 revs per minute

Using the same size motor but only 700Kv the RPM would drop to 6993 revs per minute. A drop of 30%. To get back to around the 10,000RPM of the 1000Kv motor and the same power output without changing the propeller we would need to go from a 3S pack to a 4S pack. This would give us a new RPM of 9324 (700 x 3.7 x 4 x 0.9). Still short of the 9993 of the 1000Kv motor. Assuming both motors have the same power rating (watts) the only way to increase the power would be to increase the propeller size and loading on the motor. This however could be impractical on two counts. One the diameter of the propeller could now be too large on a small model. Secondly the increased loading could increase the current draw above what the motor could handle. Next paragraph!

Volts, Amps, Watts

It is in this relationship between Volts Amps and Watts that there is the misunderstanding that leads to motors and speed controllers burning out. Each parameter has an upper limit that must not be exceeded if damage to the motor is to be avoided. You cannot achieve the maximum recommended power output (watts) using a low cell count and upping the current draw. It is a compromise between operating voltage (cell count) and operating current (propeller loading). As an example the parameters for an Overlander Thumper 3548 motor are:

Max Current = 60Amps,

Max. No. of LiPo cells = 6 (22.2v), Max.
Power Output = 770Watts.

Running the motor at 60A will produce the following power outputs : 3S Lipo pack = 60A x 11.1V = 666 Watts 4S LiPo pack = 60A x 14.8V = 888 Watts 5S Lipo pack = 60A x 18.5V = 1110 Watts 6S LiPo pack = 60A x 22.2v = 1332 Watts

As can be seen a 3S LiPo pack, if being run within the motor specification (60 Amps) it only produces 666 Watts. If using a 4, 5 or 6S pack the current must be restricted to keep it within the upper power limit of the motor (770 watts) if damage to the motor is to be avoided. 4S = 770w / 14.8v = 52 Amps 5S = 770w / 18.5v = 41.6 Amps 6S = 770w / 22.2v = 34.7 Amps

There are advantages to using higher voltage batteries that help offset some of the extra cost involved i.e.

1. A lower rated, cheaper speed controller can be used.
2. The motor is more efficient due to operating at the higher voltage.
3. There should be a minimal increase in weight because a lower capacity battery can be used without compromising flight performance because the ‘energy’ content (watt hours) will be roughly the same. To get the best out of your motor and avoid ‘system’ overload a Watt meter is a very useful tool to have. If you do not posses one closely monitor the temperature of the motor, speed controller and battery. Warm is OK hot is NOT.

Propeller Loading verses Current

Increasing the size of the propeller either in diameter or pitch will increase the load on the motor and hence the current (amps) flowing through the motor. Using the results below that were obtained when converting a 25 powered I.C. model to electric I have derived a formula to calculate the current draw for different size propellers at varying speeds (rpm). The thrust produced by a propeller is dependent on three main factors, propeller diameter and pitch plus speed (rpm). So by adding propeller RPM to the formula used to calculate propeller loading (Diameter squared x Pitch) used elsewhere on this site to produce the Propeller Loading chart we can calculate a figure for thrust that can used to calculate the power produced by a propeller of a given size at various speeds i.e.

Thrust = Diameter^2 * Pitch x Propeller RPM Thrust =

Power = Watts = Volts x Amps

The Thrust = Watts formula is not quite complete because we need a ***constant*** to bring it in line with actual test results. This done by dividing measured thrust by the measured power (Watts).

The 25 size I.C motor was fitted with a 9in x 6in propeller rotating, on full throttle, at 10,000 RPM. This was calculated to be equivalent to a power output of 330 watts (see below). Using this information we can now calculate our ***constant.***

Diameter ^2 x Pitch x Propeller RPM / power Output = ***Constant***

(9 x 9) x 6 x 10,000 / 330w = **14727.**

The formula for power now becomes:

Power (watts) = Propeller Diameter^2 x Pitch / 14727

Once we know what power is required we can divide this by the operating voltage to arrive at the expected current draw (amps) i.e. for a 3S 11.1v setup 330 / 11.1v = 29.7 Amps.

Using a 10in x 5in propeller rotating at 7500 RPM the result would be: (10 x 10) x 5 x 7500 / 14727 = 254.6w = 22.9A

There are a number of variables that will influence the results obtained in tests on the bench the main one being the make and style of propeller used. Different makes and shapes will produce different results so if you find that the formula above does not work with the ***constant*** I have used do your own test with a watt meter and tachometer and calculate your own ***constant.***

Practical Advice

How long is a piece of string! If you are moving from I.C. power to electric probably the best advice is in the Simple Electrics article. Determine what I.C. motor you would use in the model. Identify the maximum power (BHP) of the motor. Divide this by 1.5 i.e. 2/3s and multiply by 750 to convert the BHP to watts to determine the output power of the equivalent brushless electric motor. Taking a 0.25 cu.in. (25) engine as an example.

Typical power output of a 25 size motor is 0.66 BHP using a 9in x 6in (225mm x 150mm) propeller turning at approximately 10,000 RPM.

0.66 BHP / 1.5 = 0.44BHP x 750 = 330 watts

Using a 3S 11.1v Lipo battery the current draw to produce 330 watts = 330 Watts / 11.1 Volts = 29.7 amps.

Using a 9in x 6in propeller turning at 10,000 RPM we can now determine the motor Kv (revs per volt).

Motor Kv = 10.000 / 11.1vx 0,9) 1,000 Kv ahora tenemos una

especificación de motor. salida de potencia mínima de 330

vatios mínimos valoración actual recuento de células 30

amperios mínimo 3S o 11.1 voltios

Usando la regla 1.5 / las dos terceras partes de un margen de seguridad conservadora la especificación del

motor sería Potencia máxima - 495 vatios, actuales máximos - 45 Amperios

Tensión de trabajo - 2 - 4S (7.4v - 14.8v)

De la gama Overlander Thumper 35xx hay una serie de opciones. Motor Kv Max

		Watts Max	Nº amperios	Las células	Volts Watts	Fuera	RPM Comentarios	
3530 1100 315			30	2-4	11,1 330		1099 Max	Vatios / amperios
3536 1000 480			30	2-4	11,1 330		Max 9990 Amperios	
3542 1250 580			45	2-4	11,1 330		12.488 RPM alta	
3548 900 770			60	3-6	11,1 330		8991 RPM baja	
3548 900 770			60	3 - 6 14,8 330			11988 RPM alta	

From the list the 3530 is out for being too low powered. The 3536 is working at the maximum current limit. This could be overcome by increasing the battery voltage to 14.8v but this would increase the propeller RPM and changing to a smaller propeller. The RPM is a little high on the 3542 and would necessitate changing to a smaller propeller to hold the current at 30 Amps although the motor is capable of turning the propeller at the higher RPM. Having reserve power is useful for getting out of trouble so with a small compromise on propeller size this motor will fit the bill. The Kv is low on the 3548 so to produce the power we can either increase the size of the propeller or increase the battery voltage to 14.8 volts. At the higher voltage the propeller RPM is a little high and the same comments re the 3542 apply. Either motor will be suitable. Neither motor is being overworked and both have good reserves of power. The 3548 is 30 grams (1 oz) heavier than the 3542. Incidentally the above example proved itself when I converted my Peppi EPP power model to electric. There was very little difference in performance between the I.C. and the electric versions

If you have no idea of the equivalent size of an I.C. motor you would fit in the model there are a number of charts available that calculate the watts per pound / kilogram for different types of model. Once you know the power (watts) required then follow the guidelines in the preceding paragraphs.

To Sum Up

If you understand and follow the general principles outlined above then the motor you select should meet your requirements with good safety margins. If the motor does not live up to initial expectations then there are still a number of options available such as increasing the battery voltage and changing propellers. When changing propellers try different brands of the same size. They all produce different results in the model. I once changed the propeller on my I.C. model for one of the same size but a different brand and was surprised at the difference in performance. Do not forget the golden rule. The higher the cell count the smaller the prop! Another rule re propellers is the coarser the pitch the faster propeller will want the model to fly and the less thrust there will be at low speed and for steep climbs. Fine pitch for slow models, coarse for go-faster models.

Espero que este artículo ha sido útil y ayudado a entender las variables que tienen que resolver la hora de seleccionar un motor sin escobillas para su modelo. Una cierta cantidad se ha dado por hecho que sea sencillo. Se trata de los conceptos que son importantes en lugar de la ciencia!

Buena suerte

Stan