Borders Model Boat Club

About DC Electric Motors and Speed Controllers

Motor Size Designation

A motor is often designated by a number such as "540". This does not relate to its operating voltage, current consumption or power output, but is merely an indication of the physical size of its casing. All that "540" means is that the motor is 54 mm long! So a "Speed 400" motor is about 40mm long. The designation tells you nothing else about the motor. So the question "Is that speed controller suitable for a 540 motor?" cannot safely be answered.

A company, such as Johnson, manufactures motors for many applications, and have a range of standard case sizes. Suppliers, such as MFA purchase motors from them, and rebadge them for retail. It is the number of turns that are wound onto the armature that decide the properties of the motor, and that will vary depending on the purchasers application. As a result you can find a large variation of power outputs amongst motors of identical appearance.

If you purchase, say, a "540" motor, from a dealer in surplus motors, you will not know what you are buying. He will have bought up a manufacturers overun, and probably has no idea of the specification.

If you pay a bit more for the motor and buy a branded one, badged as, say, "Graupner Speed 400", or "MFA385/1", the supplier will have had the motor manufactured to a particular specification, and will have published the voltage, current, rpm etc you will get from that motor. You will know what you are getting. These suppliers list the properties of their products on the Internet.

Brushed & Brushless Motors

The electrical current flowing through the armature windings creates a magnetic field, and so is attracted or repelled by the field magnets fitted inside the casing. To keep the armature turning, the direction of the current flowing through the armature windings must be reversed as it passes the magnetic pole. Traditionally this has been done using a commutator and carbon brushes, but more recently it has been done electronically, hence the terms "Brushed" and "Brushless". Brushless speed controllers do the necessary switching.

Brushless motors are generally more efficient and tend to be smaller and lighter than brushed motor of the same power. They run at higher speeds, and must have an electronic controller to make them work. You can't just connect them to a battery. Their applications in model boats would appear to be for electric racers.

Because a brushless motor does not rely on the rotation of the armature to switch the current direction, often the armature is fixed, and the casing, complete with field magnets does the spinning. These are called "Outrunners".

In the modelling world, brushless motors and controllers are mostly set up for model aircraft applications, ie speed controllers without reverse. Again, an electric flight fanatic will probably be using LiPo batteries, so their voltage ratings are usually expressed in terms of a lithium cell voltage, which is nominally 3.7 volts. So a 2S motor is one designed for use at 7.4 volts. However this does not mean that the motor (with controller) cannot be used with other types of battery, such as a 6 cell NiMH (Nickel Metal Hydride) battery.

Brushless motors have speed ratings quoted as KV value. This refers to the no load rpm, and is given by the rpm per volt of the power supply.

Motor Properties

The speed at which an electric motor runs depends on the number of turns on the armature. Those intended for model aircraft use will have less turns, so that they turn faster. Motors suitable for model boats will have more turns so that they turn slower.

More powerful motors will tend to overheat, and often have a small cooling fan inside adjacent to the commutator. If a motor runs hot, a cooling coil of copper tubing can be wound round it, and water from outside the hull can be passed through the coil.

Small dc motors tend to run too fast for direct connection to a propeller, and require to be geared down either using a gearbox or a pulley drive system. Some motors are sold with a suitable gearbox attached. The range of step down ratios required is between 2:1 and 5:1 to get a propeller speed of 2000, 3000 rpm.

The properties you need to know are:
Brushed or Brushless
Dimensions
Operating Voltage
Current at Maximum Efficiency
Power
Stall Current
RPM

Selecting the Motor Size for a Model

This is very difficult, as there are a lot of unknown, but important factors. You must consider the drag and “C_M” effects of the model and the shape of the hull in the vicinity of the propeller, and of course, the design of the propeller. Model boat propeller seem to be sold by diameter, and usually no data is available for blade area or pitch.

The simplest, and best method for selecting a motor and propeller is to look at what is used in another boat of similar size and type, and do the same. Naval Architects usually resort to model basin tests to get data for full size designs, because propeller theory is not very accurate.

If scaling is required, because you can’t find a good match, the propeller diameter can be scaled in the ratio of overall lengths, and motor power by (ratio of overall lengths)$^{3.5}$. For a scale model, the motor power and propeller diameter of the full size ship can be scaled using these rules to get a first size estimate.

According to the Froude scaling rules, the operating rpm should be scaled upwards by the square root of the scale factor, but this is pointless when you are limited to the pitch, blade shape and area of a commercially available propeller. It is better to gear down the motor to run at 2000 to 3000 rpm top speed, because propeller cavitation is likely to be the most important design consideration.

If in doubt, select the next size up in motors. While you can always take less than the rated power from a motor, you can’t take more than the rated power without overheating.

Speed Controllers for Brushed Motors

There are many speed controllers on the market. Some are basically a rheostat which is operated by a servo, and some are electronic. Nowadays the latter are most common.
The older electronic speed controllers (ESC) send pulses to the motor at the transmitter frame rate (about 50 Hz). The length of each pulse determines how much power is available to the motor. At low speeds the motor may appear a bit "lumpy".
More modern speed controllers (often known as "Squealers" because of the noise they make) also send pulses, but at a higher frame rate of 1kHz to 4kHz.

A good speed controller will also incorporate a circuit known as BEC (Battery Elimination Circuit). This produces a stable nominal 5 volt supply for the receiver and servos, so that a separate receiver battery is not necessary.

Before buying an ESC look to see what other Club Members are using. Seek advice on how reliable and how repairable etc each make is.

When selecting an ESC the following parameters are important considerations:

Brushed or Brushless motors
Maximum and Minimum Operating Voltage
Maximum Continuous Operating Current
Maximum Short Term Overload Current
Adjustments to suit the transmitter throttle pulse range, ie centre and span adjustment.
Forward and Reverse
Are you using a LiPo Battery? (Does the controller prevent over discharge?)
BEC
Is it Repairable? (If encapsulated, it is not.)
Cost
Physical Size

Current Rating Requirement for a Speed Controller

To a small extent, this is set by the internal components of the ESC, but a brief overload will not cause damage. A sustained overload may cause overheating, and result in a MOSFET failure. Such an overload might be caused by a propeller getting stopped by a build up of water weed. If this is likely to happen, the stall current of the motor is the figure you should use to select the ESC. If it is completely unlikely to happen, then the maximum efficiency current times 1.3 may be used, and you can accept the fact that motor stalling might burn out the ESC.
It is a good idea to fit a slow blow fuse in the supply lead to an ESC, with a value set at the maximum operating current. A sustained overload will blow the fuse, and save the ESC.

BEC

The design of the BEC circuit determines the maximum and minimum operating voltages of the ESC. Some makes quote a minimum operating voltage of 6 volts, while others quote 7.2 volts. This affects what batteries you will have to use.

Look at the BEC current rating. Most have a maximum BEC current of 1 Amp, and this will happily supply the receiver and several servos. A well designed BEC circuit "folds back", reducing voltage if the current limit is exceeded. Cheaper ones burn out. (The minimum supply voltage quoted is a good indicator. 6 volt minimum supply types will probably "fold back", 7.2 volt ones probably will not.)

Note that if two or more speed controllers are being used, only one of them should have BEC enabled. If BEC is being used, no receiver battery must be used.

LiPo Battery

Since Lipo batteries will be destroyed by an over-discharge, ESCs suitable for use with LiPo batteries will have some cut off device to prevent this happening.