A Guide Book To Electric Motors

By Andy Griffiths

It's now over 4 years since the then editor asked me to write an article on motor care. A few things have changed since then, so this can be seen as an update. If you read my previous article you may recognise a few bits but I've tried to add some new hints and tips based upon the new technology available and from things that I have learnt in the last few years. I'm also going to discuss in more detail how to choose the right motor for you as with the plethora of motors and classes now, the choice is becoming more and more difficult.

How do they work

The majority of electric motors used in R/C models originate from the same source in Japan. These motors are then either sold in bulk direct to car manufacturers to be supplied in kits or supplied as 'Teardowns" (motors with no windings) to independent motor manufacturers to build into competition motors for sale through model shops.

In general, the design of these parts really hasn't changed a great deal in the last 15 years. A lot of the pioneering development work in producing true competition motors instead of the basic motors that were available at the time, was made by Demon Products in the UK and by Parma in the USA. At this time the only motors available were 'tuned' 540 kit motors - now found in Tamiya and other cars. These then developed into the motors we refer to today as Standard or Stock motors. The biggest development being the ability to change brushes by having the brush system on the outside. It may be hard to believe but at this time all World Championship events were won using what today would be referred to as a Standard motor!

The next step was the introduction of the Modified motor, where the motor could be taken apart for cleaning and rebuilding, allowing different winds to be used. This step also prompted the introduction of many of the big motor names that we know today. Also it became possible for small firms to take a bite of the action. The advancement of battery technology also helped, allowing the further development of faster, more powerful winds. This is basically where we are today with just minor changes in design in the last few years.

Basic Principles

It doesn't matter what type of motor you use, they all operate using the same basic principles. Inside the motor can there are two permanent magnets. These magnets provide a constant linear flow of magnetic flux (the name given to the invisible substance that causes the magnetic effects that we can feel) from North to South across the can. Similarly to electric current, magnetic flux needs a complete circuit for it to be able to flow properly. This is why two empty cans will not stick together, where as two complete motors will. The motor can and armature stack are both made from highly conductive materials in order to provide a magnetic circuit inside the motor. Iron and steel are both good conductors - air is in fact a very poor magnetic conductor. This is why it is best to have as small an air gap between the armature stack and the magnet faces as possible. It is also why the latest motors feature thicker cans.

The bit that spins

The next major component is the armature. This is the part of the motor that spins and it consists of the commutator - made from copper and the stack - made from iron and containing the all important windings. These two components are pressed and bonded onto a stainless steel shaft.

The stack is divided into 3 poles each with a coil of wire . The commutator is again divided into 3 with each segment corresponding to a coil of wire. The coils transform the electric current provided by the battery pack into a magnetic field which then opposes the field produced by the magnets, causing the armature to move. The electric current is conducted to the commutator via the brushes. Only one coil operates at any one time, and as the armature tries to move, the commutator segments act as a switch, turning off one coil and turning on another. This switching effect causes the armature to rotate smoothly by ensuring that only the coil that is perpendicular to the field is supplied with current, making sure that none of the coils fight each other. It is in fact the switching that causes sparks and hence wear and interference to occur. This is why it is so important to keep the brushes and commutator in good condition. The more poles, the smoother the turning effect. In R/C motors we use three poles because this provides a good combination of torque and 'smoothness'. More poles would be difficult to manufacture at this size and would also reduce the torque.

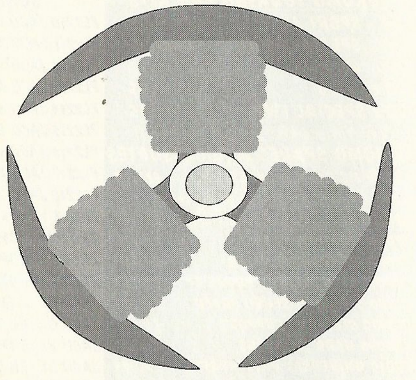
It's all in the magnets

The basic performance characteristics are governed by the magnetic field strengths produced by the magnets and the armature coils. Presuming that the magnets are of a constant strength, then we can control these characteristics by changing the coils. The strength of the coil field is governed by the number of turns of wire and the amount of current flowing through them. Because of the nature of the formula that derives this effect, current is the most important factor, hence the voltage applied across the motor effects the RPM greatly. However, because the number of turns effects the resistance of the wire and hence the current, this also effects the RPM, as does the cross-sectional area of wire. The formula also states that the number of turns of wire will effect the torque produced by the motor. Basically each effect is linked to the next and things, as you can see, get ridiculously complicated. To simplify things a little;

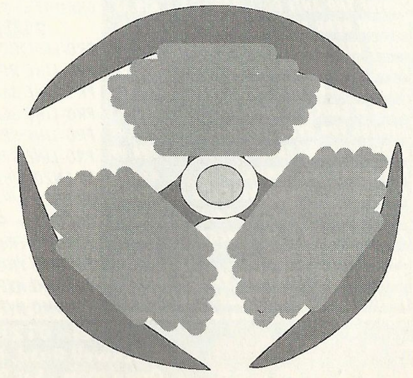
Low number of turns = High RPM, High current draw, Low torque, small pinion

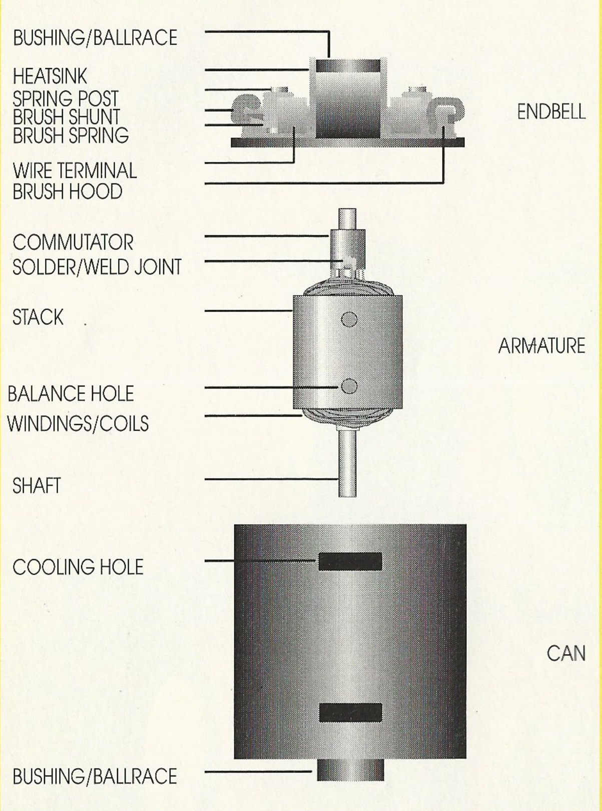
High number of turns = Low RPM, Low current draw, High torque, Large pinion

SMALL CROSS SECTION ARMATURE



LARGE CROSS SECTION OR 'FAT WIND' ARMATURE





Number of winds

You will also have heard of motors being referred to as having a certain number of winds. This is the number of wires that are wrapped around any one pole. For example, a 15 turn single wind has one piece of wire wound around each pole 15 times. A 15 turn triple has 3 pieces of wire wound around each pole 15 times. The actual wind does not effect the performance of the motor, it is the cross-sectional area of wire that governs the performance as this is what controls the resistance of the coil, hence the current flow around the coil. For example, a single wind with a very thick piece of wire may have a higher cross-sectional area than a double wind with two very thin wires. Again, a simplified description gives;

Large cross section = Faster acceleration, more current draw, higher efficiency

Small cross section = Slower acceleration, less current draw, lower efficiency

You can see the difference between a large cross-sectional area wind and small cross section in the diagram.

We usually find that large cross-section motors work best in 4wd and On-road, whilst small cross section motors are good in 2wd or slippery tracks where you can't get the power down. Small cross section motors are also good on very large or power sapping tracks. These are generalisations but do apply in most cases.

Don't be fooled

Stronger magnets will also produce faster acceleration as they increase the torque. Don't be fooled into thinking that high torque always means fast acceleration though. Sure, if 2 motors have the same RPM and current draw etc. but one has d higher torque, then that motor will accelerate faster. However, gearing has a huge effect on acceleration. This means that a motor with a low number of turns will in general accelerate faster than a motor with a high number of turns, even though the high turn motor has more torque. This is because we have to adjust the gear ratio in order to make the run time (not go flat). A high RPM motor will draw a lot of current and so must use a small pinion as this makes it easier for the motor to get the car moving. This in turn makes the car accelerate quickly, while the high RPM means that the top speed will be just as quick as a low RPM motor with a big pinion. Achieving good acceleration is a combination of torque, RPM and gearing.

If you go flat before the end of the race, use a smaller pinion. This should also be done if the motor is excessively hot. If the smaller pinion makes the car too slow down the straight, go to a higher turn motor and use a bigger pinion.

If you have plenty left in your cells after the race, go to a bigger pinion. If this reduces the acceleration, go to a lower turn motor but on a smaller pinion.

It must be in good condition

This only applies if the motor is in good condition. A motor in poor condition will cause duration problems, as will badly matched or old batteries. If the car gradually gets slower halfway through the race but easily lasts, getting slower and slower, then the chances are the cells are the problem. It is also possible to use too small a pinion. This will cause the car to go flat because the motor is over revving. In other words it is at full speed too often. This causes over heating, resulting in the cells going flat. If you are geared unusually different to someone else using a similar motor, try their ratio. If the problem persists, move to a higher turn motor. You could also consider having the 'problem' motor checked over by a professional rebuild firm such as MG Model Products.

Track conditions can effect duration greatly as well. Tight tracks with lots of stop-start sections will require a smaller pinion, as will wet and muddy tracks or high grip surfaces such as carpet. Large, open tracks and low grip, dusty tracks are easier on cells and can allow you to use a larger pinion.

Choose a motor

In general for competition use in Off-road we use motors in the range of 11 to 13 turns. Touring cars prefer 13 or 14 turn motors. If you want extra speed but are not actually racing, then a Standard or Stock motor is a good choice. These are 27 turn motors and can be a direct replacement to a 'kit supplied' motor. Use a smaller pinion than that came with the kit and you will notice a considerable increase in speed. They're cheap as well! Bare in mind that a low turn motor could damage the transmission and electric's in a budget class car.

I've put the table below together as an aid to motor and gearing choice. It is only a rough idea as the ratios can be considerably effected by motor/car/track/driver conditions but they could be a useful start. Gear ratios are quoted as:-.

$$\frac{\textbf{No teeth on spur gear}}{\textbf{No teeth on pinion}} + \textbf{Gearbox Ratio = Overall Ratio}$$

ie:- Losi XX

$$\frac{\textbf{88(spur)}}{\textbf{13 (Pinion)}} + \textbf{2.19 (gearbox ratio) = 8.95:1 Overall}$$

A table of ratios is usually in the kit instructions. Some popular gearbox ratios are;

Cat/Cougar: 2:1
Losi XX : 2.19:1
RC10 B: 2 2.4 :1

Touring car ratios are more difficult to recommend as the tyre diameters can range substantially. In this class I would only recommend asking some one who appears to have got things right but remember to take into account the diameter of their tyres. Larger tyres will gear up the car, ie similar to using a bigger pinion. Also try to take into account that most people exaggerate there ratios for some strange reason!

We would usually run an 11 or 12 in 4wd and a 12 or 13 in 2wd. A fourteen can be good in 4wd if duration is a problem. In Touring cars a 14 is the most popular with a 13 being used on a smaller track. Again, Large cross section (fat wind) in 4wd or small track; and Small cross section in 2wd or if duration is a problem.

Hopefully this article may help in some way with choosing your motor. Some of it was probably a bit boring or over technical but it can help to understand how to make your car go quickly.

Next time we'll be looking at how to keep your motor going quickly and I'll give some hints on how to get a bit more out of your motor.

Motor	2wd	4wd	High RPM, High Current Draw, Fast Acceleration
11 Turn	9.8-10.5:1	11.2-11.8:1	
12 Turn	9.4-10:1	10.5-11:1	
13 Turn	8.7-9:1	9.5-9.8:1	
14 Turn	8.3-8.6:1	9.2:1	Low RPM, Low Current Draw, Lower Acceleration