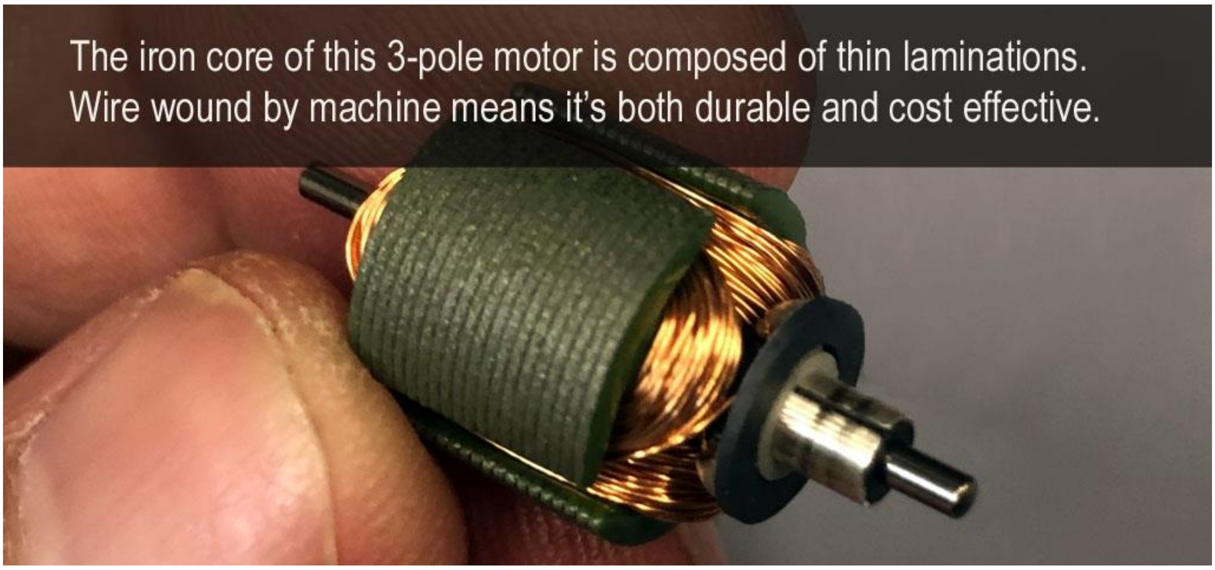
What´s inside of a RC servo?

Intro

There's no surprise a motor inside your servos is what converts the electricity from the battery into the force that powers your servo's control horn, right? The real question is; what kind of motor is inside. Is it: DC/iron core, coreless, or brushless? What follows holds true for **any** RC model servo you buy… from any brand! Yes, regardless of whether it's from Futaba, Sanwa, KoPropo, RC OMG, Reve-D, Yokomo, Savöx or any other brand. It has one of these 3 types of motors inside! The point being, this article is good reading no matter what brand of servos you favor! Anyway, let's delve into the subject and find out more!

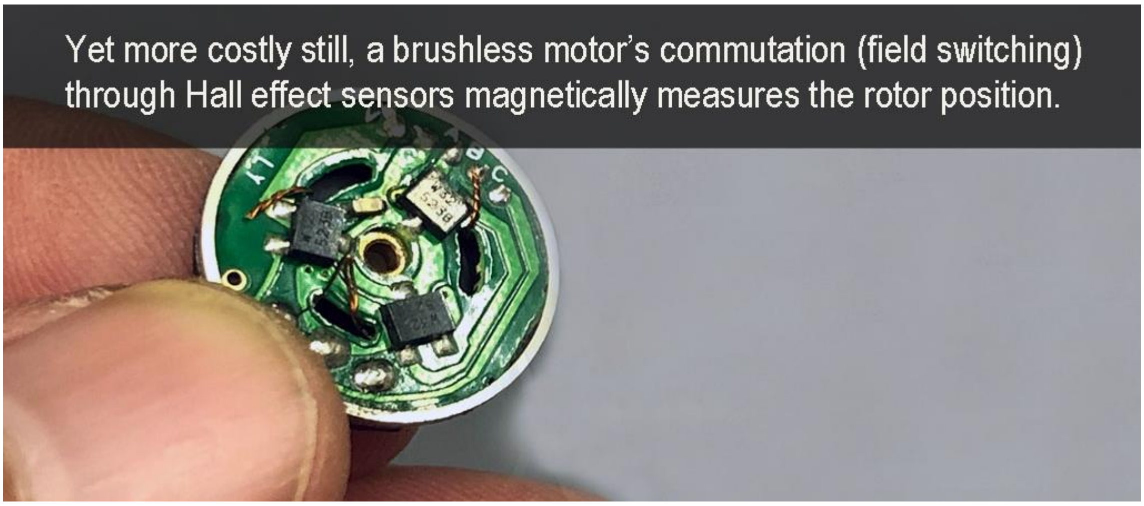
Note: DC motors have been around the longest and cost the least. And technically, DC-motor is a misnomer. DC is really more than only one type because it includes coreless as well, so it's more accurate to say iron-core instead of DC when referring to a 3-pole motors except DC is the accepted industry nomenclature for ferrite-magnet iron-core motors. Is what it is so please allow me the leeway to use DC-motors to represent the ubiquitous iron-core motors available in the market, e.g. an ordinary 3-pole. And while we're at it, brushless motors are actually AC motors, but more regarding this, later!

DC-motor servos: What's most important to know about DC-motors is that they are (by far) the easiest to make and thus, they're the cheapest. Basically consisting of a bit of copper wire coiled around iron cores for the electro-magnet, a can lined with a ferrite permanent magnet, plus a commutator ring and brushes (to switch the fields). Along with a way of holding the shaft at each end, you've got a DC motor that's very cheap and easy to make - and durable, too.



Coreless motors: these are significantly more expensive than DC-motors because of how they are made and because of the materials themselves. Their principal advantage over a DC-motor is they accelerate/decelerate more quickly. This is because of how the windings are made. They're formed on a mandrel (a more expensive process) and rotate without an iron core. As a consequence of the ultralight rotating mass they are very quick to accelerate/decelerate, which is THE performance benefit. Commutation (field switching the windings) is mechanical - similar to how it's done with iron-core motors. However, making the delicate basket-like coils (winding) is a separate process that's more expensive (by a lot). Add to it, the permanent magnet is usually an exotic alloy of neodymium and while coreless motors make for faster servos, they are also more expensive to make. So, are you surprised you'll pay more for servos with coreless motors? Not if you follow the manufacturing process of this technology!

Brushless motors: are also called electronic motors and are quite accurately described as pricey! This is because they're manufactured similarly to a coreless motor with respect to the delicate windings and the superior magnets. But beyond mandrel-formed coils and more costly magnets than found in DC-motors, the relatively inexpensive mechanical commutation is replaced by electronic commutation. This brings benefits regarding longevity, and regardless of the direction you approach it, time is always money! Bottom line? Brushless motors are the most costly to make - their use is part of why you pay the most for servos with brushless motors!



So which one is the best? There is only one answer: It depends

Part 2:

If you stopped reading after 5-minutes, you know the basics of what goes into DC, coreless, and brushless motors, and a little bit about why they cost what they cost. That's fine as far as that goes.But there's more to know. A lot more and this requires we go a lot deeper when divining the details regarding the makeup of servo motors. As before, we'll progress from DC, to coreless, and then to brushless. But now more in depth.

Once you've fully read this section you'll understand which type of motor is best for you as determined by the technology and your circumstances, e.g. for whichever type of model and the available budget considerations. Moreover, you'll never again be dependent on someone else to help you because you'll probably be more informed than others about the composition of servo-motors and know how to judge for yourself which is best for you!

DC/ iron core-motors:

If you want cheapest, then get DC/iron core-motor servos. Shop around because servos with DC-iron core motors cost the least. That doesn't make them bad, or junky. In fact, they're perfect for a beginner, ambitious modeler or for large scale applications.

All these are easily controlled by DC-motor servos because the maneuvers they're called on to perform are within the wheelhouse of durable DC-motor servos - of any brand! Bottom line? DC-motor servos are nearly perfect for this type of flying because their characteristics serve the majority of models. Note; DC-motor servos - by their massive nature of construction - offer very high levels of torque. Power is good!

Coreless motors:

What if you want a fast servo? Then it's coreless motor servos for the win by far! Once you get into a given level of transit speed, sub-0.12sec/60°, then the servos tend to use coreless motors. When the race isn't just one of high torque, but includes an emphasis on speed also, then coreless motors become the choice.

Speaking of speed in servos, speed is costly for the same reason as going fast in real motorsport! As for why coreless motors cost more, in part it's because of how their coils are made, which allows coreless motors to be so fast when accelerating/decelerating. Added to that, they use superior magnet technology (more costly). So with servos as with anything else . . . more speed means more money!

Brushless motors:

What if durability enters the equation? Electronic motors cost more to make than mechanicals. Basically, you can't replace cheap little bits of metal used for commutation with Hall effect sensors and a logic circuit for the same price. Electronics simply cost more. Added to it, now you need more electronics (the logic) to control the motor in the ways that were once achieved by a metal ring and brushes. Is this worth the added expense? Basically yes.

Usually adding parts is bad, right? The thing is, electronic motors, brushless motors in other words because Hall effect sensors and a circuit board replace the mechanical commutation, offer a whole new level of flexibility and control to offset this. Added to that, brushless run cooler because the heat of arcing at the contacts is gone. After all, the dust created as the metal of the brushes vaporizes has to go somewhere, and the somewhere is coating the inside of the motor. This is bad for many reasons, heat and fine particles of grit chief amongst them.

When it comes to electronics, heat is never a good thing. Add grit plus small parts and it leads to a bad mixture. Anyway, this means on average a brushless motor simply lasts longer because they don't have brushes to wear. Min 5 times longer.

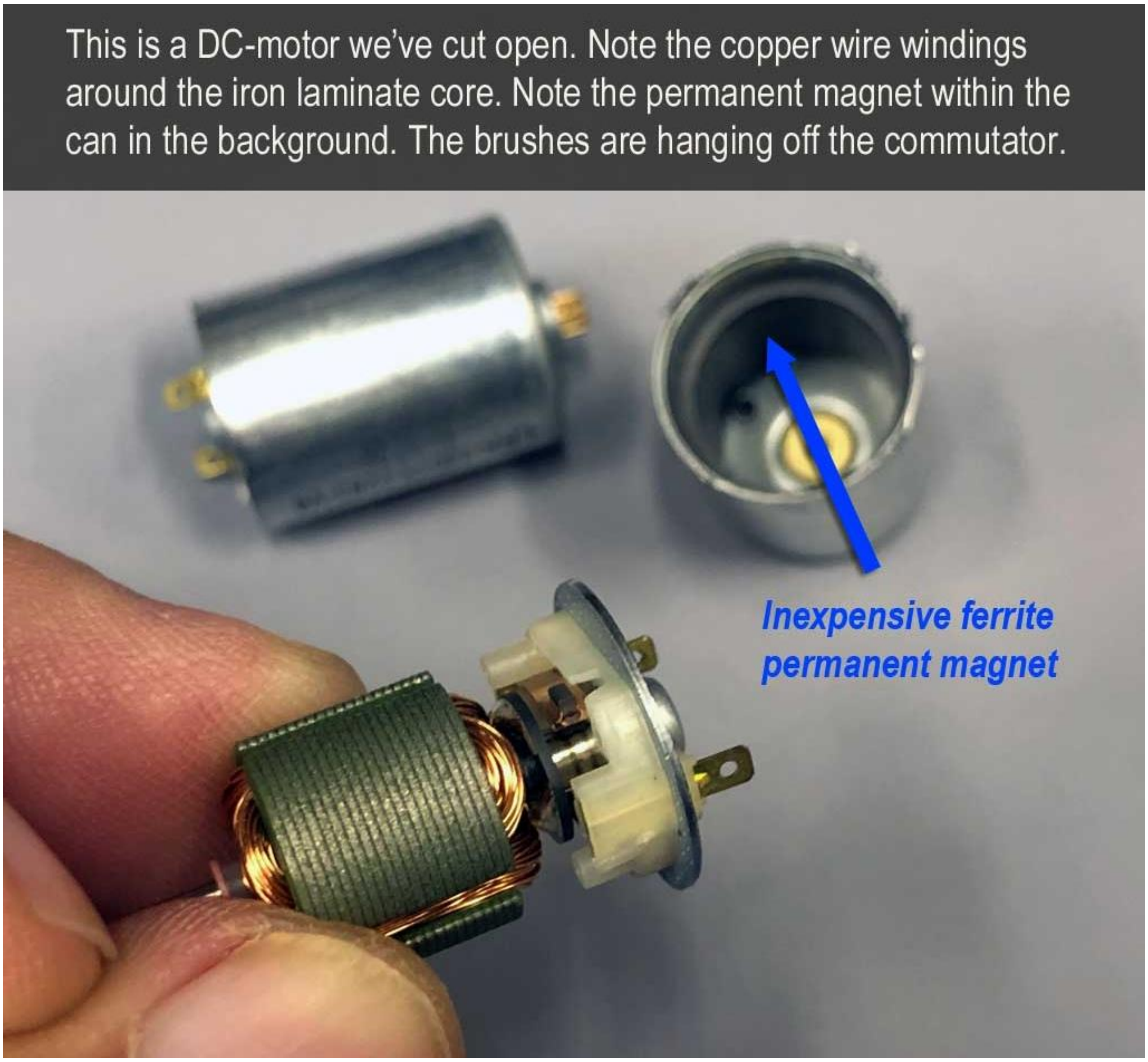
Can these things, fast, longer lasting, strong and cooler running, defend a high price like 100€ or more versus 80€? For many guys the answer is yes. Especially if you're an *'high-end'* kind of guy, or the guy who buys good stuff to be in the knowledge, that the good stuff pays off in the long run. Put another way, price isn't everything.

But honestly, things are easy when you're a single issue buyer. Cheaper, faster, more durable - pick one! Things get more complicated when you want cheapest 'and' most durable. Let's see the inside of these types of motor to better understand why the costs factor as they do. For this, let's destroy some. How? By cutting into a few motors!

Part 3

DC (iron-core):

This is a DC/iron core-motor once again. This time you're seeing the guts of how they're made. There's a ferrite permanent magnet within the can, and by winding copper wire around an iron core to generate an electromagnetic field, the windings may be sequentially energized to spin the motor.

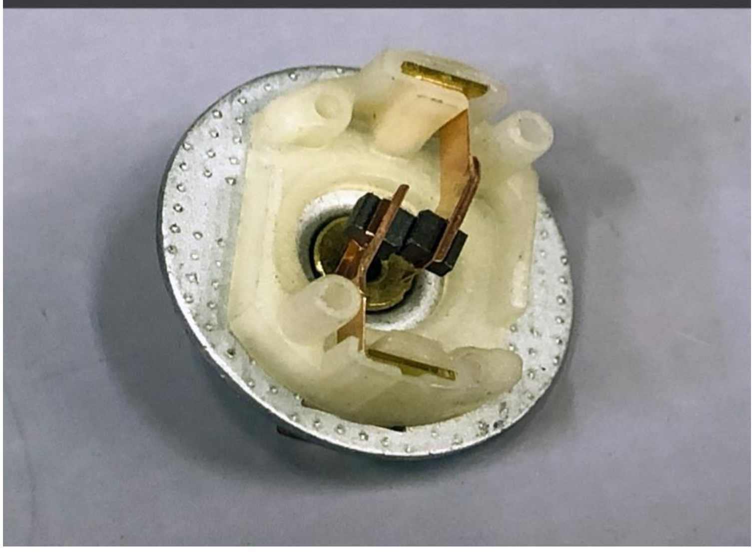


This is a DC-motor we've cut open. Note the copper wire windings around the iron laminate core. Note the permanent magnet within the can in the background. The brushes are hanging off the commutator.

Sequentially turning the windings on, thus making an electromagnet to react against the permanent magnet mounted within the can, is what moves the rotor around and around. Commutation (switching the fields on and off in a sequence) is what times the force that keeps the rotor turning.

The iron core of a DC motor is the heaviest of any type of motor. The rotor core is made of thin sections or laminations stacked together. The thinner the laminations, the lower the iron loses and the more powerful the motor.

Remember, DC-motors are basically the cheapest to build. Fortunately, DC motors are reliable, powerful, and fast enough for nearly any modeling need. This means savvy buyers, even when you can afford brushless, may opt for DC, regardless. Why? It's because it may make better sense for the application. E.g. a scale model where the speed doesn't require a pricier motor within it's servo.. Moreover, DC motors are durable too; witness the huge brushes ensuring a long life. Often, the trick to savvy buying is matching the best made servo mechanics along with an DC-motor to get the best deal.

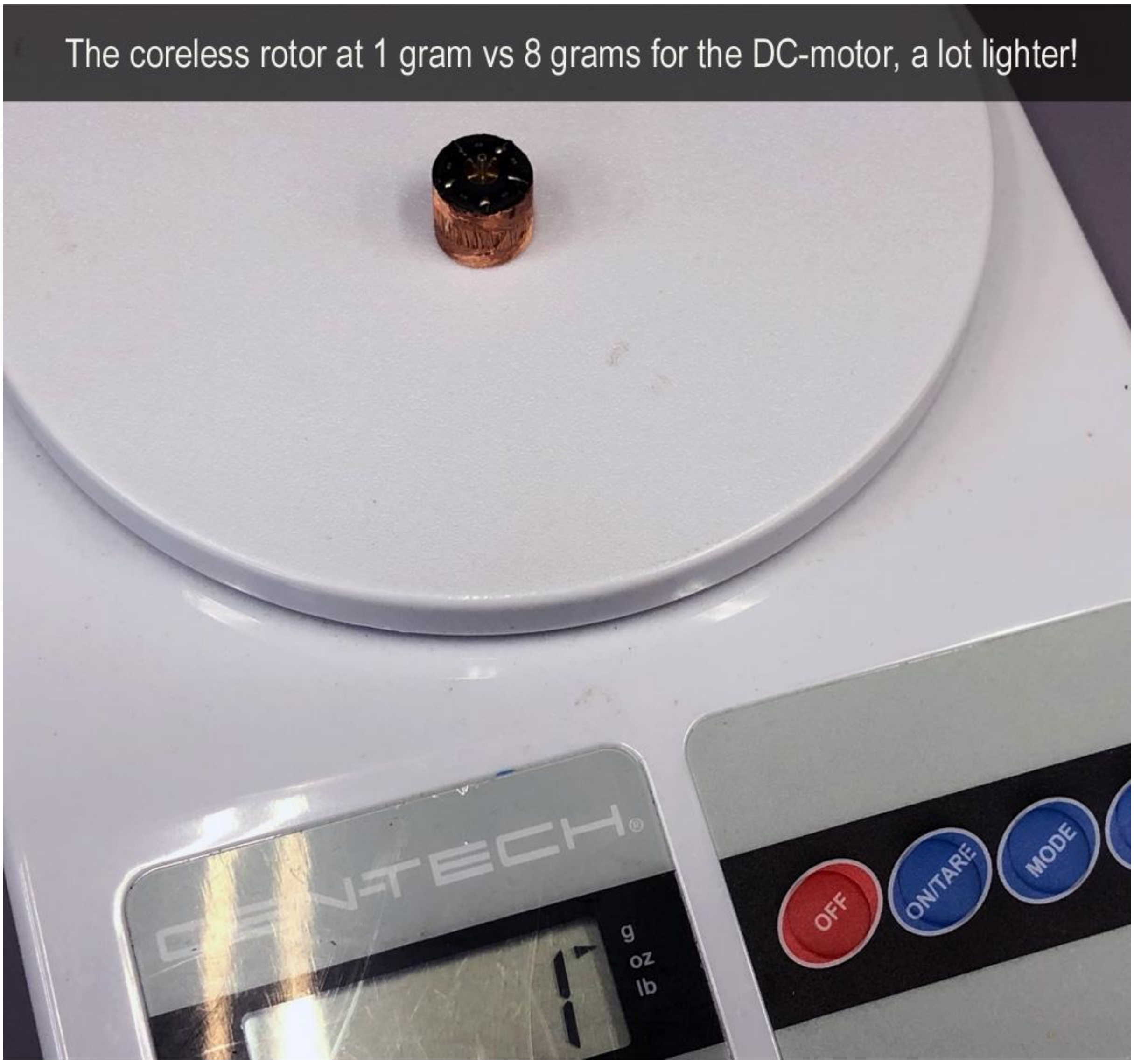


These are huge brushes. They're so large expressly because they handle the current inrush to keep this massive rotor turning smoothly.

Coreless:

These are the guts of a coreless motor. Note the wire has been wound on a mandrel and once it's retracted it leave a wire basket that doesn't weigh squat - meaning - it's super easy to both accelerate and decelerate . . . this is how you make servos react quickly!

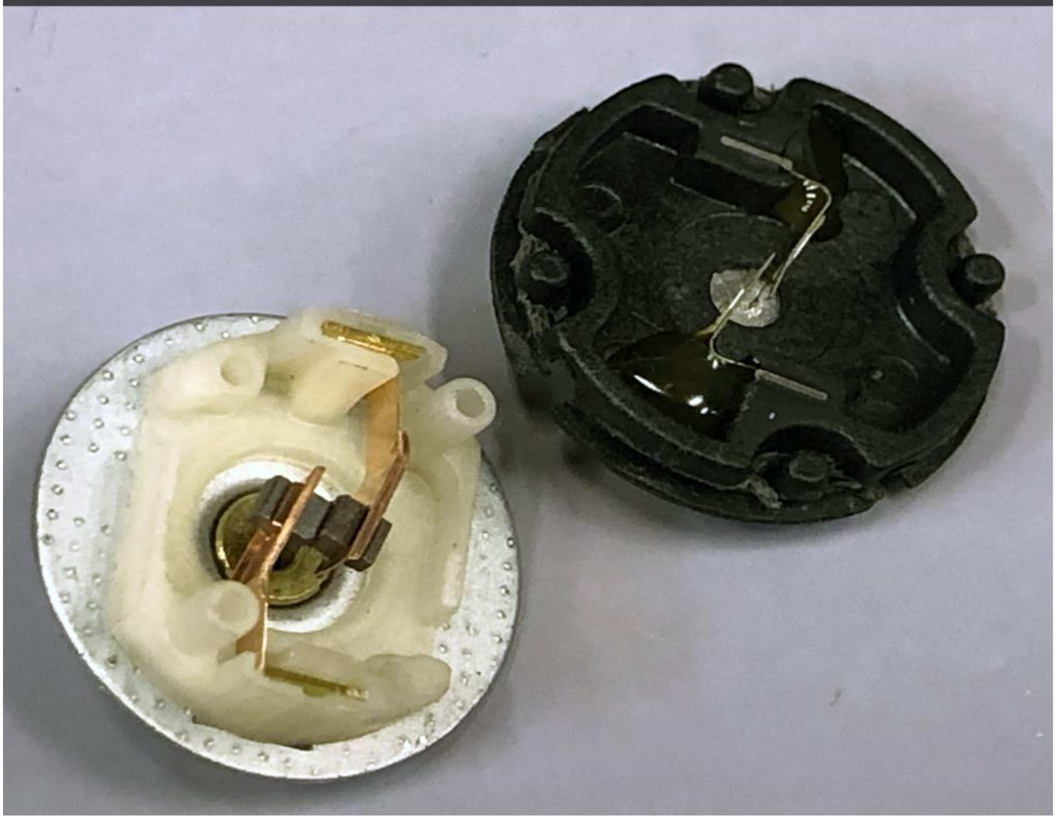
The key advantage is that these windings without a core simply weigh less. In fact, their mass is a small fraction of what the iron-core within a DC-motor masses, which means it's easier to start and stop moving. Understanding coreless motors' advantage lies in the fact their rotor doesn't weigh much by comparison. This is why they can be accelerated so much faster than an iron-core DC-motor. But winding these coreless coils costs more. Also more costly is the type of magnet, neodymium. These are the strongest permanent magnets available commercially and between this and the mandrel formed windings, higher costs versus the ordinary iron-core motors can't be avoided.



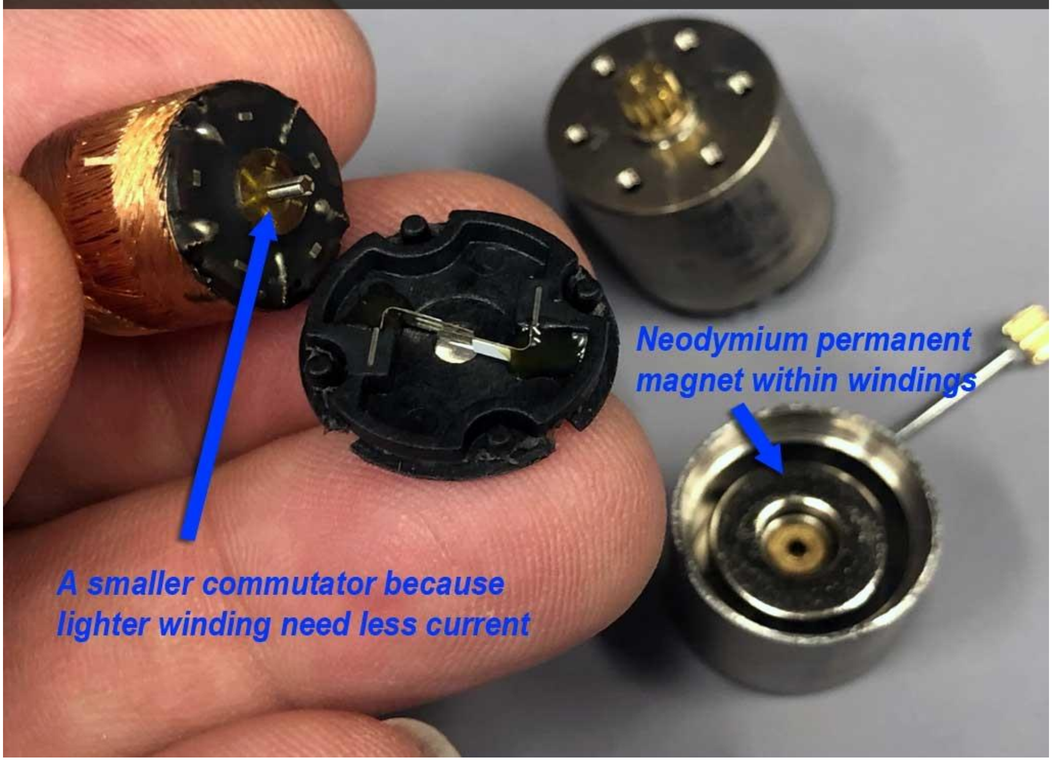
Bottom line? If speed matters, coreless beats DC every time because the mass being started and stopped is 'greatly' reduced. Commutation is still mechanical by a commutator ring and brushes. This means they wear out eventually but the brushes are a lot smaller.

Coreless motors, due to their reduced mass, require less amperage to start and stop. Thus, their brushes are more compact (smaller brushes are used). Also you can see how they're bent slightly that when they wear they maintain good contact with the commutator

Massive DC brushes on the left vs. slender coreless motor brushes.



Note how the commutator ring is split. This is how sequential turning on-and-off of the windings work through the action of the brushes.



Brushless:

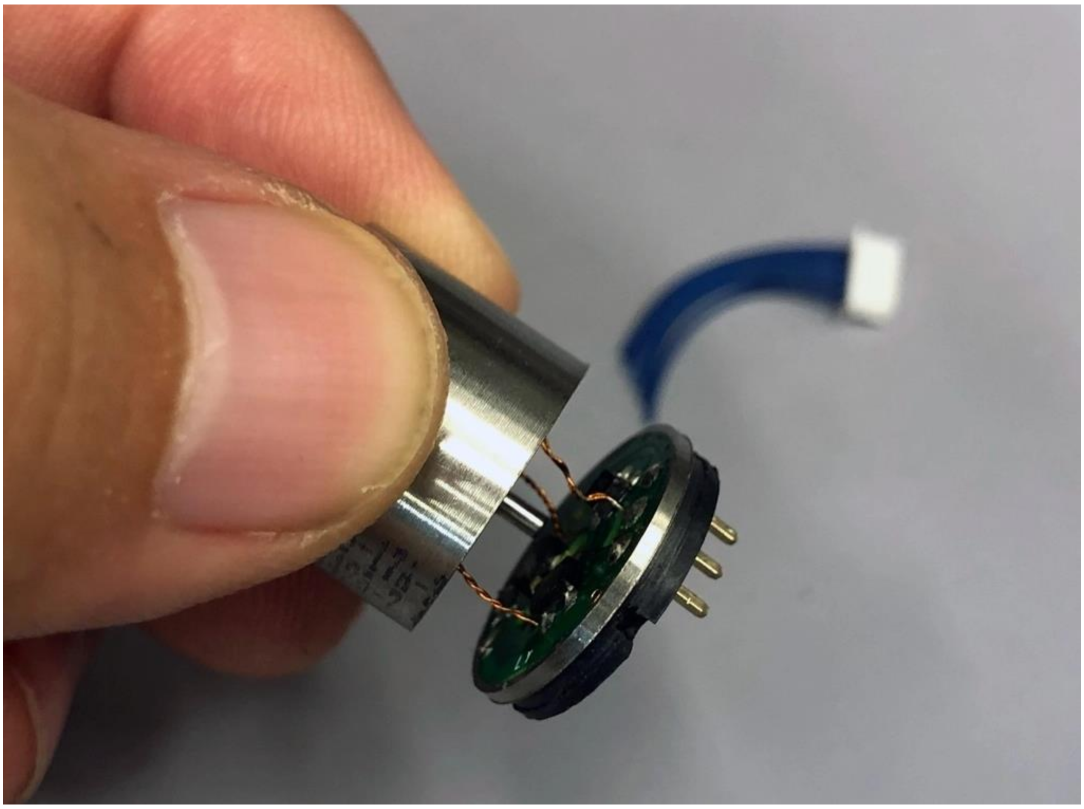
The third and final motor we'll cut open is a brushless or electronic motor. The electronics for commutation versus mechanical bits are why brushless motors are significantly more expensive to make than coreless because otherwise, brushless motors also make use of permanent magnets made from an alloy of neodymium, iron, and boron to form the Nd2Fe14B tetragonal crystalline structure that results in the incredible development in recent years of super servos.

However, while the neodymium type magnets are shared in common with coreless motors, once the relatively cheap to make mechanical parts that make up the commutator ring and brushes are replaced by electronics, costs take another leap higher. And it's a never ending cycle because, for example, the motors are more complex in other kinds of ways, even in terms of the number of wires going into them. For example, instead of two wires connecting this motor, now there are eight!

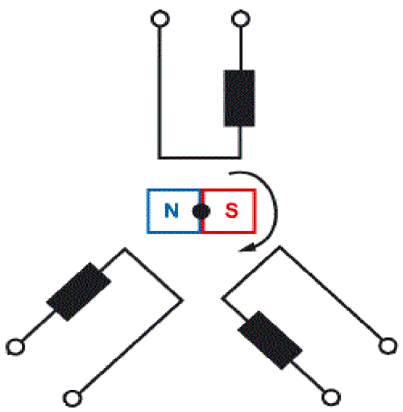
Next, note brushless motors are also wound using a mandrel. The point being, just like coreless motors, brushless motors are also used for high performance servos because they'll accelerate/decelerate more quickly than iron-core motors

Thus, due to their similarly reduced mass, it means a brushless motor also generally eclipses a DC/iron core-motor in the speed department (but at a higher cost than coreless because of the added electronics). In this motor, the rotor is static magnetic and here the coils are part of the stator - in effect, it's been built inside out! The very low weight rotor plays a role in high performance.

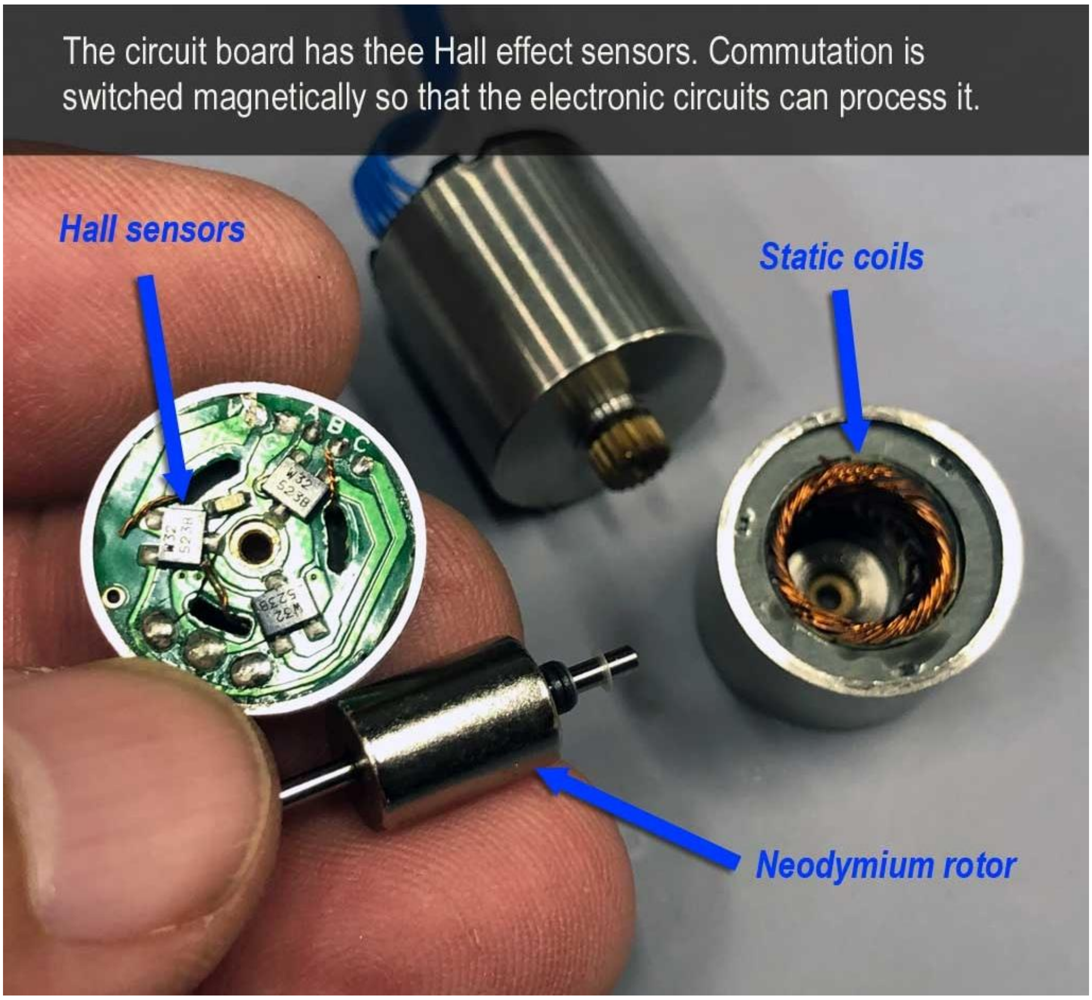
However, it's when we cut this motor apart that reveals something new and different. There are 3 wires connecting to a round circuit board section.



So what replaces the brushes? The answer to that is simple; what replaces brushes are Hall effect sensors. Their output voltage is directly proportional to the magnetic field strength through it. These are usually combined with threshold detection so that it acts as a switch.



Brushless motors are also known as electronic motors. The all sensors measure magnetic fields so that the position of the rotor can be computed and the driving voltages to the coils (windings) can be adjusted. Thus, the Hall sensor literally measures the position of the rotor based on magnetic fields . . . meaning all it has to know is which sensor produces the highest reading!



Principal advantage of brushless motors vs. coreless motors is the mere fact there are no brushes to wear out! This means the motor lasts longer. Much longer. So much longer!

The downside? There's added complexity for electronics, but they're reliable so the real downside is just one . . . cost.

Summary:

DC motor equipped servos are least expensive and good enough for 70% of models. This is the technology as old as our hobby!

The point is: buy fast, strong and reliable servos if you NEED them. Otherwise, buy the best DC-motor servos you can find. Just because the fact the motors are inexpensive doesn't mean they're junk, or poor quality. It is principally an issue of manufacturing that results in DC-motors costing less. So for scale models or extra functions who needs the fastest and most powerful servos on the market.

High performance models are the product for which coreless motor servos exist. When you're racing (any type of touring cars, 8^{th} or 10^{th} scale buggy or truck or even drift) it's important to hit the apex of a corner timed perfectly, there's no substitute for speed. Bottom line? When it comes to speed, coreless and brushless motor servos are the right answer.

What happens when longevity factors come along with speed? Then it's brushless! Clearly because the benefits outweigh the drawbacks. The same is true when 'the best' is part of the equation, e.g. where brushless motors are again the choice.

Closing:

In the end, whether you're facing a budget, or the requirements of the model are guided by a single factor, perhaps torque, the DC-motor servo is probably all that's needed. They are a great choice for almost any model. The point is, most modelers can select a DC-motor servo based on torque requirements and only some modelers need to spend more than the 50€/servo For those who do, it's because servo requirements including the speed and ultra torque parameter. Competitors will fall into this category when performing high speed maneuvers often making a coreless servo the best choice. As for those of you for whom a brushless-motor servo is essential, your needs dictate you the servos for which, basically, money is no object. You want the best and are willing to pay for it! Brushless motor servos are the best money can buy.

If you've made it through this entire report then you're fully equipped to decide what motor is best for you based on what you've learned.

Thank you for reading my roundup

Hope, you enjoyed it

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