A Guide to Understanding LiPo Batteries

Introduction

Lithium Polymer batteries (henceforth referred to as “LiPo” batteries), are a newer type of battery now used in many consumer electronics devices. They have been gaining in popularity in the radio control industry over the last few years, and are now the most popular choice for anyone looking for long run times and high power.

LiPo batteries offer a wide array of benefits. But each user must decide if the benefits outweigh the drawbacks. For more and more people, they do. There is nothing to fear from LiPo batteries, so long as you follow the rules and treat the batteries with the respect they deserve.

Lithium-Polymer batteries contain, quite obviously, **lithium**. Lithium is an **alkali metal**, meaning it reacts with water and combusts. Lithium also combusts when reacting with oxygen, but only when heated. The process of using the battery, in the sometimes extreme ways that we do in the R/C world, causes there to be excess atoms of Oxygen and excess atoms of Lithium on either end (be it the **cathode** or **anode**) of the battery. This can and does cause Lithium Oxide (Li_2O) to build up on the anode or cathode. Lithium Oxide is basically corrosion, albeit of the lithium kind; not iron oxide, which is otherwise known as "rust". The Li_2O causes the internal resistance of the battery to increase. Internal resistance is best described as the measure of opposition that a circuit presents to the passage of current. The practical result of higher internal resistance is that the battery will heat up more during use.

How to best maintain your battery in order to have maximum performance and life span. Some of you might know this already, but it is never bad to review your knowledge, yet some will regard it as new, and will learn something useful, which could potentially save them money and frustration in the long run.

First of all please understand that, the life and performance of a Lipo battery is critically affected by the way the battery is broken in, and the way it is maintained. The sooner you realize that and start treating your batteries properly, the sooner you will notice the benefits of this little effort.

Voltage / Cell Count

A LiPo cell has a nominal voltage of 3.7V. For the 7.4V battery above, that means that there are two cells in series (which means the voltage gets added together). This is sometimes why you will hear people talk about a "2S" battery pack - it means that there are 2 cells in Series. So a two-cell (2S) pack is 7.4V, a three-cell (3S) pack is 11.1V, and so on.

What is Nominal Voltage?

Nominal voltage is the default, resting voltage of a battery pack. This is how the battery industry has decided to discuss and compare batteries. It is not, however, the full charge voltage of the cell. LiPo batteries are fully charged when they reach 4.2v/cell, and their minimum safe charge, as we will discuss in detail later, is 3.0v/cell. 3.7v is pretty much in the middle, and that is the nominal charge of the cell.

In the early days of LiPo batteries, you might have seen a battery pack described as "2S2P". This meant that there were actually four cells in the battery; two cells wired in series, and two more wired into the first two batteries in parallel (parallel meaning the capacities get added together). This terminology is not used much nowadays; modern technology allows us to have the individual cells hold much more energy than they could only a few years ago. Even so, it can be handy to know the older terms, just in case you run into something with a few years on it.

The voltage of a battery pack is essentially going to determine how fast your vehicle is going to go. Voltage directly influences the RPM of the electric motor (brushless motors are rated by kV, which means 'RPM per Volt'). So if you have a brushless motor with a rating of 3,500kV, that motor will spin 3,500 RPM for every volt you apply to it. On a 2S LiPo battery, that motor will spin around 25,900 RPM. On a 3S, it will spin a whopping 38,850 RPM. So the more voltage you have, the faster you're going to go.

Capacity (mAH)

The capacity of a battery is basically a measure of how much power the battery can hold. Think of it as the size of your fuel tank. The unit of measure here is milliamp hours (mAh). This is saying how much drain can be put on the battery to discharge it in one hour. Since we usually discuss the drain of a motor system in amps (A), here is the conversion:

1000mAh = 1 Amp Hour (1Ah)

It is said that the capacity of the battery is like the fuel tank - which means the capacity determines how long you can run before you have to recharge. The higher the number, the longer the run time. Airplanes and helicopters don't really have a standard capacity, because they come in many different sizes, but for R/C cars and trucks, the average is 5000mAh - that is our most popular battery here in the store. But there are companies that make batteries with larger capacities. Traxxas even has one that is over 12000mAh! That's huge, but there is a downside to large capacities as well. The bigger the capacity, the bigger the physical size and weight of the battery, and it is expensive to ship due to IATA Dangerous Goods Regulation. Another consideration is heat buildup in the motor and speed control over such a long run. Unless periodically checked, you can easily burn up a motor if it isn't given enough time to cool down, and most people don't stop during a run to check their motor temps. Keep that in mind when picking up a battery with a large capacity.

Understanding “C” Rating

Let start off by understanding **what the battery's "C" rating means**. C rate is the battery's maximum **SAFE** continuous discharge rate. If the label says "20C" that means that the battery can be discharged at a rate of up to 20 times the capacity of the battery, until it is depleted. Capacity refers to the milliamp-hour rating of the battery, which will be listed as a number followed by "mAh" - 2200mAh. Some brands also use Amp ratings, which is pretty much the same, just a different scale, so 2200mAh will be displayed as 2.2. Keep in mind that 1000mAh equal 1Amp. So here is an example with a 2200mAh 20C pack (pack voltage does not play a part in determining C rating):

2200mAh = 2.2Amps
2.2Amps x 20C = 44Amps continuous discharge

This means that you can safely draw up to 44Amps from that pack, without damaging it. That is only the theory however, in reality, some of the cheaper battery brands tend to over-rate their batteries, which causes a lot of people a lot of frustration, and dramatically reduces the battery's life span.

Breaking in batteries

So let’s start from the beginning. Irrespective of the battery's voltage (cell count), C rating, or capacity, **ALL NEW BATTERIES MUST BE BROKEN IN** before they are used on a model, or for whatever application they were intended for. And this is how it works - all batteries have a "C" charge rate, in addition to the "C" discharge rate. Usually, the charge rate is much smaller than the discharge rate. Some brands claim that you can safely charge their batteries with up to 8C charge rate, but this would be foolish, and experience has proven that doing this, shortens a battery's life dramatically. Especially for the break in cycles (1 cycle refers to one charge and one discharge of a battery), the battery MUST be charged and discharged at 1C. So, for example, if you have the above mentioned 2200mAh 20C Lipo, you must set your charger to charge it at 2.2Amps, and then discharge it again at 2.2Amps. It is recommended to put new batteries through 6-7 break in cycles at 1C, before putting them in a model. Most modern chargers have automatic programs for battery cycling, so you just have to input the number of cycles, and the charge and discharge rates, start the program and wait for it to finish. With older chargers you will have to manually start every charge and discharge program, until you complete 6-7 cycles.

Charge C ratings are usually indicated on the label on the back of the battery. However, not all brands indicate that, so make sure you ask for your specific battery's charge C rating when you buy it.

Another important thing to know, is to set the low voltage cut-off of the discharge part of the break in cycles. Setting the cut-off voltage to 3.5v per cell during the discharge part of the break in cycles is a good way to give the battery a nice work out, and also for you to determine its true capacity. Standard tests have repeatedly shown that when you discharge a battery down to 3.5v per cell, at 1C discharge rate, when the low voltage cut-off engages and stops the discharge procedure, the battery has been pretty much completely discharged. During the first 2-3 cycles, the battery will not charge or discharge to its full capacity, but on the following cycles you will see that the amount of charged and discharged mAh will get closer and closer to the mAh capacity written on the label. You might also notice that some brands have a real mAh capacity slightly larger than the stated one, while others have real mAh capacity slightly smaller. A smaller real mAh capacity does not mean the battery is bad, it usually means it might be lighter than a comparable stated mAh capacity / C rate / voltage Lipo from another brand. On average, new and good batteries should discharge close to their stated mAh capacity, when discharged to 3.5v per cell at 1C discharge rate.

Battery charging

Now, we come to charging the batteries during the course of their life span. Battery charge C rates vary between 1C, for Tx and Rx packs, to 8-10C for high performance packs. Most batteries have a charge C rate between 2C and 5C. NEVER charge batteries at more than 1.5C, and that is only at the field, Always charge them at 1C. Experience has proven that really expensive, high-end Lipos do have a long life span (over 300 cycles), even when constantly charged at 4-5C, however, these batteries cost quite a lot, and either way. Cheaper, and more popular Lipo brands do suffer from high charge C rates, and in some cases like helicopters, people are replacing them every 50 cycles, because they can feel the oncoming lack of performance. Helicopters, however, are just one part of the hobby, and is a special case. Helicopters are generally very demanding of the batteries, so 50 cycles are actually pretty OK for packs used in extreme 3D heli's.

In any case, opinions will differ - some people do not bother to wait for 30-40 mins for a pack to charge, so they charge at high C rates, and replace their packs more often. But it is better to have more battery packs per model, so often you don't even need to charge at the field, so all of the charging is either at 1C or 1.5C at the most. At the end the decision is up to you - whether you want your batteries to last longer, or have fewer charges. There is one thing that people should be careful about - when you receive your battery, if you want to charge it at rates over 2C, make sure you KNOW for a fact that the battery CAN handle more than 2C charge rates, otherwise you run the risk of ruining it very quickly, or even making it to explode.

(The safest charge rate for most LiPo batteries is *1C*, or 1 x capacity of battery in Amps.)

Battery discharging

Now it's time to discuss discharge rates. Some people, for some reason, think that the battery's capacity or discharge rate should be used to limit motor power, or also think that just using higher capacity batteries will overload the motor!!! And here's why: in no universe should a battery's discharge rate be used to regulate motor output!!!! This is wrong on so many levels

When we choose a model, unless it comes with the power system already installed, we should choose the power system in the following order: first is the motor, and preferably one that could provide sufficient power for the model, then, and only THEN do we go about choosing an appropriate ESC and battery.

So here is an example - if the selected motor has a max amp rating (that is the maximum amount of amps that the motor can SAFELY draw continuously) of 20Amps, a 20Amp ESC would work, but preferably it should be at least 25, or even 30Amps. The battery used for this motor should be capable of providing around twice the maximum amp draw of the motor: for a 20Amp motor, a suitable battery would be 2200mAh 20C, because it can provide max of 44Amps, which is twice what the motor could ever draw.

While adhering to these principles, two things will always be a fact: under full motor load, the battery will be strained at only 50%, which means less voltage drop, which means more power goes to the motor, which translates into more thrust, and the battery will not be over-stressed, will not overheat, will not puff up, and generally will last MUCH longer. Trying to do the opposite - to limit motor power by using a lower discharge rate battery - will end up over-stressing your battery, it will puff up, and it will last only a few cycles. Not to mention, that the motor will drop considerably, because the battery voltage will drop very low, and will not provide enough power to the motor. As a general thumb rule, try to use a battery that can provide twice as much current as the motor can draw. This will ensure your battery's longevity and will definitely improve the flight performance of your model.

A LiPo cell should NEVER be discharged below 3.0V

Another **VERY** important factor to increasing the life of your batteries, is the use of a PROGRAMMABLE Low voltage Lipo alarm in your models. Those are the Lipo alarms that display battery pack and cell voltage on a screen, and have a button for adjusting the alarm voltage. For optimum flight times, and depending on the battery's state, the alarm should be set anywhere between 3.4v and 3.6v per cell. When the alarm sounds be quick to land, otherwise you run the risk of completely depleting the battery, which is not good for the battery, but it could also potentially crash your model.

Storage Mode

Proper LiPo Storage Voltage = 3.8V per cell

And last, but not least, we come to battery storage. For long term storage, the batteries should be discharged or charged, depending on their current state, to around 3.8v per cell. That voltage will ensure that the battery will not be damaged over long periods out of use, and will also prevent the voltage from dropping too low due to self-discharge. Most modern chargers should have programs for charging/discharging batteries to storage level voltage. As a general rule **NEVER** leave your batteries charged for more than one day. Some people might argue that even one day is a long time for a Lipo battery to stay charged. It is recommended to always charge the batteries one day before you get to the flying field. If you know you are not going to be using some batteries for a long time - anything from a week to over a year - make sure you discharge/charge them to 3.8v per cell before you store them.

As long as the voltage is 3.8v per cell, the Lipos should be OK to sit for a long period. Well, that about concludes it for now, so if you've understood at least half of the information above, your batteries should last much longer.
LiPo batteries offer plenty of power and runtime for us radio control enthusiasts. But that power and runtime comes at a price. LiPo batteries are capable of catching fire if not used properly - they are much more delicate than the older NiMH/NiCd batteries. The problem comes from the chemistry of the battery itself.

Internal Resistance

Higher Internal Resistance = Higher Operating Temperature

As we touched on earlier, some modern chargers can read the internal resistance of the battery in milliohms (mΩ). If you have one of these chargers, you can get a sense of how your LiPos are performing, and how their internal resistance increases as they age. Simply keep track of the internal resistance reading each time you charge your battery, and chart the increase over time. You will see how just the process of using the LiPo battery begins to wear it out.

Heat causes the excess oxygen to build up more and more. Eventually the LiPo pack begins to swell (due to the oxygen gas build up). This is a good time to stop using the battery – it's trying to tell you that it has come (prematurely or not) to the end of its life. Further use can, and probably will, be dangerous. After the pack has swollen, continued use can cause even more heat to be generated. At this point, a process called Thermal Runaway occurs.

A Swelled, or Puffed, LiPo

Thermal Runaway is a self-sustaining reaction that is accelerated by increased temperature, in turn releasing energy that further increases temperature. Basically, when this reaction starts, it creates heat. This heat leads to a product that increases resistance (more $Li2O$), which causes more heat, and the process continues until the battery bursts open from the pressure. At this point, the combination of heat, oxygen, and the humidity in the air all react with the lithium, resulting in a very hot and dangerous fire.

However, even if you stop using the battery when it swells, you still have to render it safe. If you puncture a LiPo that has swollen and still has a charge, it can still catch fire. This is because the unstable bonds that exist in a charged battery are in search of a more stable state of existence. That's how a battery works; you destroy a stable chemical bond to create an unstable chemical bond. Unstable bonds are more apt to release their energy in the pursuit of a more stable bond.

When a LiPo is punctured, the lithium reacts with the humidity in the atmosphere and heats up the battery. This heat excites the unstable bonds, which break, releasing energy in the form of heat. The Thermal Runaway starts, and you again get a very hot and dangerous fire.

The entire process of building up that lithium oxide usually takes around 300-400 charge/discharge cycles to reach a tipping point. That's a typical lifetime of a LiPo battery. But when we heat the batteries up during a run, or discharge them lower than 3.0 volts per cell, or physically damage them in any way, or allow water to enter the batteries (inside the foil wrapping), it reduces the life of the battery, and hastens the buildup of Li_2O.

LiPo Battery Disposal

So you have a bad LiPo battery? No one really wants to keep them around (fire hazards that they are). So what is the process to get rid of a bad LiPo battery safely? Let's go through it.

1. **Discharge the LiPo battery as far down as you safely can**. You can do this a number of ways. Most computerized LiPo chargers have a discharge feature in them. If you don't have a charger with a discharge feature, you can run down the battery in your vehicle - keep in mind that you risk a fire and potentially damaging your vehicle doing this, so take care to have the necessary safety equipment around. Alternatively, you can build your own discharge rig with a taillight bulb and some wire. Simply solder a male connector of your choosing to the tabs on a taillight bulb, and plug the battery in. Make sure to have the battery in a fireproof container while doing this.
2. **Place the LiPo in a salt water bath**. Mix table salt into some warm (not hot) water. Keep adding salt until it will no longer dissolve in the water. Ensure that the wires are all entirely submerged. The salt water is very conductive, and it will essentially short out the battery, further discharging it. Leave the battery in the salt water bath for at least 24 hours.
3. **Check the voltage of the LiPo**. If the voltage of the battery is 0.0V, great! Move onto the next step. Otherwise, put it back in the salt water bath for another 24 hours. Continue doing this until the battery reaches 0.0V.
4. **Dispose of the battery in the trash**. That's right - unlike NiMH and NiCd batteries, LiPos are not hazardous to the environment. They can be thrown in the garbage with no problem.

Conclusion

The above information concludes that now you know most of what you need to know about LiPo batteries. With this information you should be able to get the best performance and most cycles out the lipo battery.

Hyperion does not take responsibility for improper use of Lithium polymer batteries and the sole responsibility lies with the users themselves.