In-Flight Power Variation.

By Bob Smith

This article is about an aspect of battery testing which I have recently realized was not included in my normal procedures. Many of you will know that as well as an occasional article for EFUK I have a regular column in Q&EFI in which I report on much of the technical side of electric flight. As part of this I do bench testing of various batteries, motors, chargers, etc. and so I have a lot of data available from past work. My personal background in materials technology has led me to follow the kind of test procedures one would adopt in a commercial laboratory and one of the principles involved is to simplify the variables under test. By this I mean than for an investigation into one of a set of inter-related variables you try to keep as many of them constant as possible. I have therefore tested the discharge capacity of batteries under constant current and the static output of motors at constant voltage as examples of this approach, but there is a disadvantage.

Real Life.

In a normal electric flight power train the motor, battery, and controller are interactive. Even if we only consider full power conditions, the motor and the battery are operating in a time dependant environment. By that I mean that as the motor is running the battery is discharging, the battery voltage and current are both reducing, which therefore reduces the power into the motor and hence the power out of the motor. Everything, therefore, is changing, nothing is constant, and running tests with one or more variables held constant can leave gaps in the data. This is even before we try to take account of the effect of the model flying speed upon the system.

As an example of this, the problem which started me on this train of thought was that of power variation in flight. I started by thinking about electroslot but the reasoning applies to most electric models. The rate of climb of an electroslot model depends upon the power output of the motor. All of the climbs in the 5 rounds come from a single charge so as the battery discharges the power into the motor decreases, the power out decreases (dependant upon the motor efficiency) and the rate of climb decreases. But by how much?

What should be measured?

To get a feel for the power difference between full batteries and almost empty batteries I had to decide what to measure. It doesn't really matter what motor, prop, controller etc. are used so long as the battery is fully charged at the start and is then run at full power until the battery reaches low-voltage cut-off. For convenience the motor/prop should draw enough current to flatten the battery in a reasonable time period, and we need to record battery voltage and current as the test proceeds. The product of these will give us watts into the controller and if we assume that the controller has a constant high efficiency this will be near enough to the power into the motor. The power out of the motor needs to be measured by a dynamometer, but in the absence of this, the static thrust or even the prop RPM will give us relative values of power out.

Having decided what I needed to do I selected motors and controllers for two battery types, a 7 cell GP 3000mAh NiMH electroslot battery, and to widen the investigation, a 2S1P Kokam 2000mAh LiPo pack. I actually measured both static thrust and RPM but the graphs are only based upon thrust as an indicator of output. The actual numerical values are fairly meaningless since they depend upon the motors and props used but for comparative purposes I have included scaled axes.

Results.

The shape of the curves is the only important feature here and you will see that for both batteries the two curves are of very similar shape. What we are looking for here is the relative drop in power during the full run. Taking static thrust as a parameter equivalent to Power Out you will see that for the NiMH cells the value after the initial power burst (say 30 seconds out of a full run of 380 seconds or 8%) is some 705 g. At the end of the run (say 350 seconds out of 380 or 92%) this has dropped to 550 g. which is a 20% reduction from the earlier value, and of course this will continue to reduce at an ever increasing rate till the battery reaches cut-off.

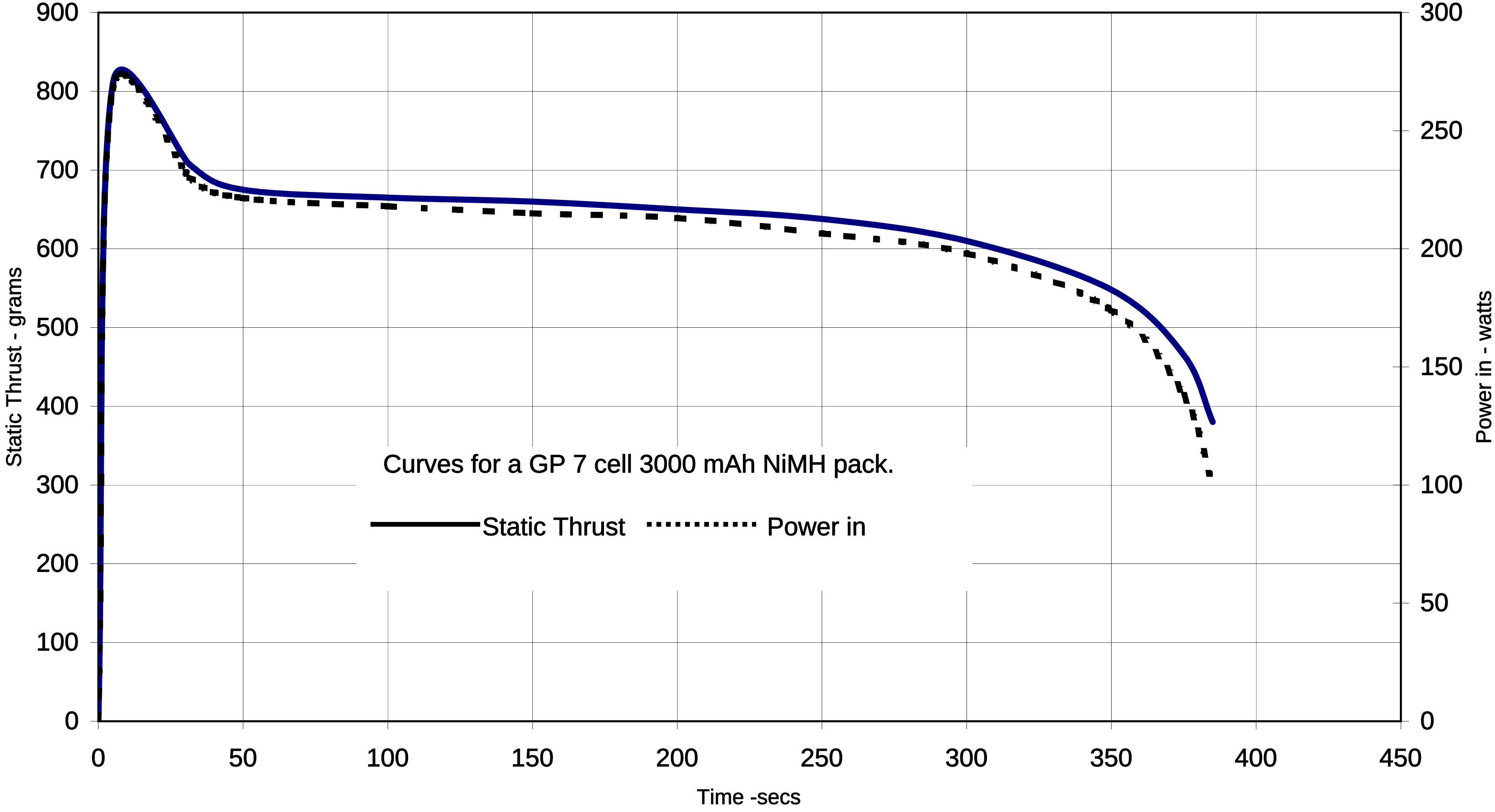
In the case of the LiPo battery the equivalent figure for the reduction in static thrust between 8% and 92% of the run is only 10% so for this test the LiPo is the better performer.

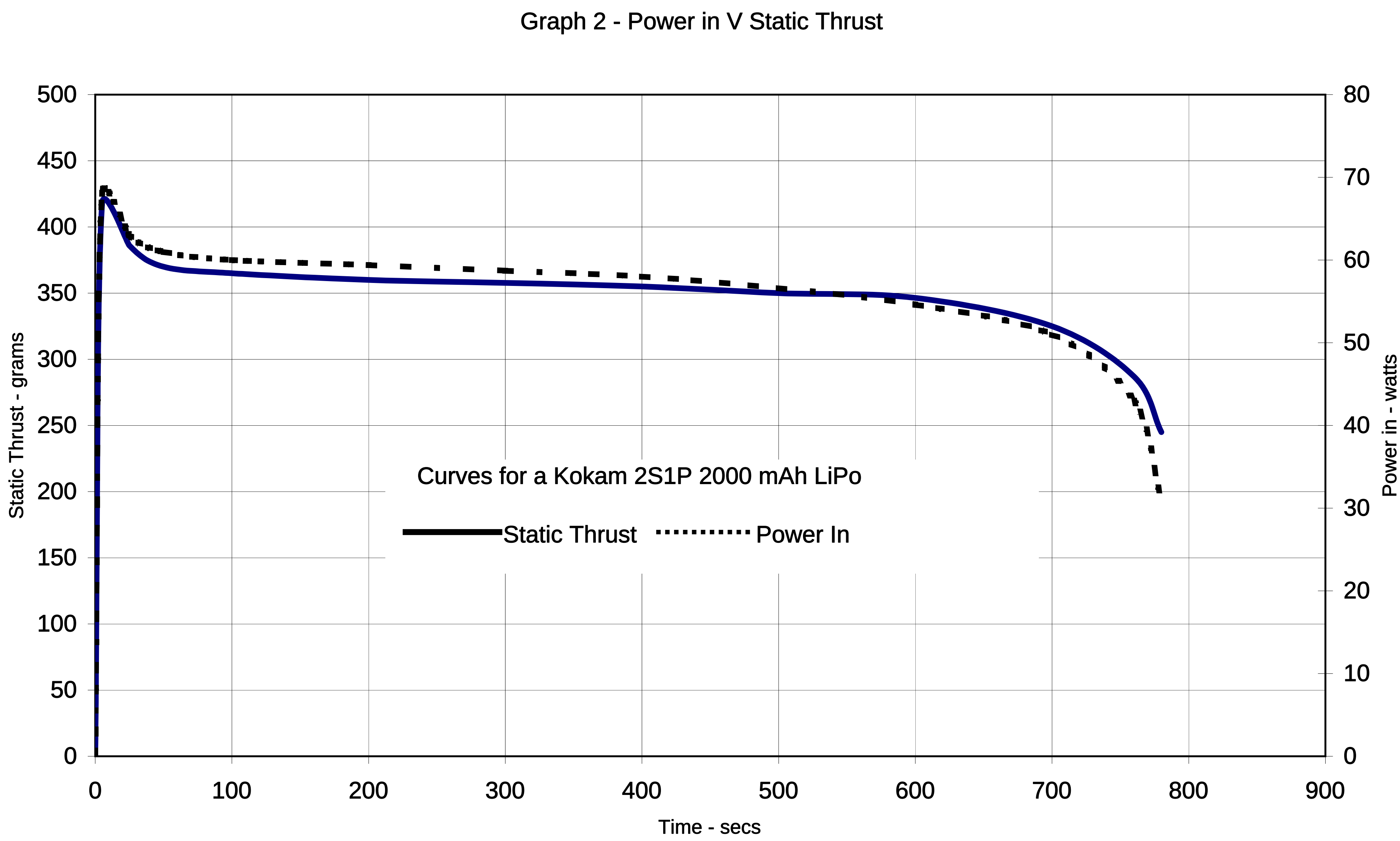
Comments.

I now have an idea of how my eslot model will drop off in performance with my final round flight only having 80% of the climb for the first round flight, but there are several factors which I need to bear in mind. The first is the usual problem of the relationship between static and in-flight performance, although this may not be relevant since I am dealing only with comparative values. Secondly there is the effect of motor efficiency. Our motors have efficiency curves which have a peak. If the motor RPM changes as the battery discharges then the efficiency will also change. We normally operate beyond the peak so that the efficiency should increase as RPM reduces, but most brushless motors have a flat curve so the changes may well be very small.

The final point is hypothesis on my part as I haven't yet had chance to check this out. I suspect that the proportional reduction in battery power is linked to the discharge rate. We can express this as we do for charge rates, i.e. as a multiple of the capacity. The NiMH cells were discharged at an average current of around 27 amps or 9C whereas the Lipos were at 8 amps or 4C which might explain their improved performance. We know that increased discharge rates do give increased voltage drop (dependent on the cell internal resistance) so it would seem likely that the power drop from start to finish of a run would then be increased, even though this is a relative value. I have to say that when I started this analysis I thought it would be fairly straightforward but I should have known better. The more I thought about it, the more complex it has become, but at least it is good exercise for the grey matter, if you like that sort of thing. If not, then I apologise for taking up the space, but the Editor has been complaining about not having enough material so you can blame him.

Graph 1 - Power in V Static Thrust





Graph 2 - Power in V Static Thrust
Curves for a Kokam 2S1P 2000 mAh LiPo
Static Thrust
Power In
Static Thrust - grams
Power in - watts
Time - secs
0
50
100
150
200
250
300
350
400
450
500
0
10
20
30
40
50
60
70
80
0
100
200
300
400
500
600
700
800
900