Engine Cranking System Characteristics and Performance

Analysis of a net-thread

10-4-10
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I was asked to take a look at a discussion on starter current demands for a Rotax 912 and appropriate wire sizes to the task. The discussion quoted some good data that was either insignificant or mis-interpreted. In no particular order, I'll attempt to address the toe-stubbers . . .

Q: I am currently wiring my 912uls which has the heavy duty starter. I was not sure how many amps it drew and have had trouble finding this info (I'm sure it's nestled somewhere in the Rotax pages). How many amps will it draw and what size wire should be run to the starter? My Kitfox came with #6AWG, however it was written prior to the heavy duty starter development. Has the amp draw changed?

A: It depends on how far the run will be from your battery to the starter itself. The longer the run the bigger the wire you will be needing. While you are at it make sure the grounds coming back to the battery from the engine are hefty too. Let us know how long your run will be and then we can make an estimation on the gauge of wire to use. I say we because I'm sure this is the kind of question that will get lots of replies.

Yes, (L x ohms/ft) describes the wiring component of total loop reistance. I published an exemplar analysis of a starter-loop voltage-drop in Figure 2-5 of the 'Connection. But unless the the battery is very remote from the engine, LENGTH considerations are small to insignificant.

Q: The positive run between my battery and main contactor is 6". From there I go to a starter contactor which is about 6" more...then I go through the firewall to the starter which will be no more than 15" away. So total distance from Batt to starter let's say 30" for a round number. I have a copper grounding bus that operates back to back on the firewall. I'm using a #2 stranded grounding strap to the engine. I realize the bigger the conductor used the better, but if I can use the # 6 wire behind the firewall without buying more wire, terminals, etc...that would be good.

A: Initially, a starter can draw as much as 80A to 100A or even more. I think the 6ga wire is a bit thin for this I think I'd go with the 2ga wire from the battery to the starter. Two reasons... 1. 2 ga wire will be able to carry the current with ability to spare (around 150A intermittent). And 2. The extra weight of 30" of wire is hardly significant to the plane as a whole.

"Initially" and "80-100 or more" are not definitive. Further, there's no acknowledgement of the intermittant

duty nature of engine cranking. Current ratings for wire are concerned with voltage drops over long runs . . . and temperature rise at ambient conditions for continuous duty designs. We know that the runs in this instance are short . . . so voltage drop takes a back seat to temperature rise. But then, engine cranking is an intermittent duty activity so temperature rise concerns are not strong.

One thing bothers me though... You said your wiring goes about 6" to the main contactor then another 6" to the starter contactor. That leads me to believe that you are drawing all the current for the starter motor through your main contactor. That is a lot of current for a continuous contactor to handle. I would wire the starter solenoid directly from the battery parallel with the buss wire and your main contactor. Then feed the energizing coil on your starter solenoid with power fed from the main contactor. That way there will be less heavy wire energized in flight and the starter cannot be engaged when the master switch is off.

BUT . . . if the starter contactor sticks, you have no way to shut off a runaway starter. This condition has proven very exciting for a number of builders. Please don't do this. ALL spam-cans take starter current through the battery contactor.

The old style starter draws .6kW. According to Lockwood, the new style starter draws less amps.
For a quick estimate using 60 amps for old style and 50 amps for new style will get you very close to what is probably real draw. Remember this engine is not too much over 70 cubic inches, not 200, 320, 360 or larger. This info I gathered was based on a 914, but would imagine the 912S would be very similar.

When you see a motor rating in watts or killowatts, keep two things in mind. The rating is for POWER OUTPUT and since few motors are 100% efficient, the POWER INPUT will be significantly higher. Further, the "rating" is firmly tied to specific conditions of temperature, load, rpm, and applied voltage. So that "rating" is essentially meaningless when you power the motor from a BATTERY and bolt it to an engine whose loads are all over the map.

Note if you run starter for 10 seconds, you should wait 2 minutes for cool down.

Don't know where this comes from. If it's "hard" data from the manufacturer, it's directly related to the combination of motor inefficiency combined with loads that cause rapid rise in internal temperatures.

I have a Odyssey PC525 mounted aft in fuse and am using #4 CCA. Others using #4 have good success, but #2 wire would be a little better.

"Good success" . . . while useful data is non-quantitative. Likewise, "a little better."

I think in your instance if #6 worked before, it will work better with the HD starter.

Agreed.

The wire I am using is copper clad aluminum. The diameter is larger than #4 copper but the resistance is just about the same. I almost took the yellow covering off the wire and stripped out strands to make it #5 to save a little weight, then heat shrink Teflon heat shrink over the strands. Sounded good, would have saved a little weight, then I realized just how much weight it was going to save from my rear pocket and idea was put in the bin.

Good thinking . . .

0.6KW = 600 WATTS
600 WATTS (at) 12 VDC (I use 12 V because you are pulling the power from the Battery)
I (current) = 600 W / 12 VDC = 50 AMPS ?But at WHAT TEMP?
Lets also use 8 VDC... Why? ?Because many starters will turn over at a much lower voltage than 12 VDC to insure starting when the battery is low and the temp too. ?SOoooo...
I = 600 WATTS / 8 VDC = 75 AMPS ?But again at WHAT TEMP?

Yup . . . you got it. There's not enough real data upon which one does a detailed quantitative analysis . . .

I have VERY STRONG reservations to where and how they came up with this 0.6KW. It sounds way - way too low. ? I'm betting that current (0.6KW) is a sustained current AFTER the initial surge. I doubt if they used a current probe connected to a digital O-Scope to capture the true current draw. ?Having?done amperage checks on small lawnmowers, they were pulling 100 Amps on a SUMMER DAY.Don't go borderline.

I can tell you EXACTLY how they came up with that number. They put the motor on a dynamometer set to apply design load. They apply rated voltage and double check to see that the motor turns at or above rated rpm. The motor meets design goals if H.P. out is equal to or greater than . . .

600/746 = 0.8 HP

What does this say about how it performs when bolted you your engine? Not a thing.

Recall that Charles Kettering was nearly laughed out of the "club of elitist engineers" when he opined that one could crank the engine a Cadillac with a motor that most folks considered to be wayyyyyy too small.

http://web.bryant.edu/~ehu/h364proj/sprg_97/dirksen/electric.html

For the past 100 years, starter motors have been sized such that they are adequate to the task for the duty cycle established in design goals. If that means that you LOAD a 1 hp continuous duty motor to 3 hp for a few seconds . . . so be it. I can suggest therefore that knowing the "rating" of

motors under discussion is not terribly helpful.

Being an electric model aeroplane flier, published numbers frequent lie. Almost always they are low because of voltage drops.

Common perceptions. If things don't perform "to the numbers" the authors of those numbers must be lying. I'll suggest that if YOUR numbers don't match THEIR numbers, the first thing you need to do is establish conditions under which the numbers were measured along with considerations for accuracy of the measurement equipment.

It's true that to achieve the same watt output with a lower voltage you need to up the amperage, in reality when you lower the voltage going to an electric motor the amp draw drops.

Not necessarily. Motor draw is directly proportional to load TORQUE. If the motor is driving a FAN, then load torque does go down as speed goes down. But how about your engine? Aerodynamic loads from the prop are quite low at cranking speeds . . . so loads are almost purely friction loads and relatively constant with speed.

I also don't know for certain if toe 600 watt number is actual amp draw or the output of motor. If it is the output of the motor then you have to add in some amp draw because the motor is not 100% efficient.

When the motor is described with a single number in watts, hp or killowatts . . . this is almost always POWER OUTPUT so the assertion that efficiency is an important component of determining POWER INPUT.

I forget who, but someone at Lockwood gave me their opinion that the 60 amp and 50 amp actual draw was probably close.

Anybody have a clamp on amp meter and can measure a 91X cranking amp draw?

AHA! When in doubt, go get the numbers. ANY sort of measurement investigation is useful but the ordinary ammeter measurement will prove frustrating. Input torque to crank an engine can vary by 2 or 3 to one over the cranking cycle depending on temperature and engine compression.

I did a Google on "starter current draw" and got 80,000 hits. I quickly looked through a couple dozen at random. NOT ONE discussion offered a PLOT of starter current versus time. ALL discussions tried to put some significance on readings taken from some hand-held ammeter display.

Bottom line is you need enough RPM to allow easy starting when it's cold out. Who cares if the wire gets a little warm. If you can't get enough RPM, then see if you can figure out how to get it up.

> **YES! The measure of cranking system performance is CRANKING RPM. This number takes account of starter performance as installed, battery performance and condition, and wiring. The "ratings" of any or all devices in the cranking system are pretty much limited to potential failure issues (gross overload to failure or long cranking cycles that get things too hot thus forcing a cool-down).**

AGM batteries have slightly higher voltage than flooded lead acid, but more important often have a higher cranking voltage.

> **The 'voltage' delivered by the chemistry is essentially the same for ALL lead-acid technologies. The magic offered by AGM/SVLA batteries is lower internal impedance which makes them perform better under load.**

I went for light and the PC545 aft mounted with #4 wires has worked well with folks with the old style starters. A PC680 with #2 wire and forward mounted will spin the engine a little quicker, but who cares if both start easily in the cold. I for one like the net lighter setup with the aft mounted battery because it is lighter and gives me a CG closer to aft than being nose heavy.

> **A lucid evaluation of options and design goals combined with proven recipes for success.**

If I read you right you like myself feel the 6Ga. feed wire is a bit on the light side. I agree if someone was to try to push 100 A through that wire it wouldn’t be long before it would heat up and cause even greater resistance.

What would you think an acceptable gauge for the starter feed wire to be? 2Ga. ground straps were mentioned.

I’m almost ready to install the battery in my 912 mod. I think I’ll have to put the battery behind the seats and that means around an 8’ run. I’m seriously considering 0Ga or 00Ga. wire. If I weren’t on floats I’d install a ground power connector.

> **Good grief! If you're on floats, it's a certainty that you're not concerned with sub-zero temperature performance. If this is a metal airplane, it's a certainty that #4 wire combined with an airframe ground for the battery will get you going in good shape. If a plastic airplane, it's STILL a high order probability that your cranking performance will be adequate in the weather conditions you're likely to enjoy flying this airplane.**

The impedance of the motor is very low until it starts to turn at a reasonable speed. If it stalls, which it might on a cold day, it will take a lot more current, start to heat up connections and resistance will increase, reducing current still further.

The only reason a cranking system might suffer a 'stalled' motor is a weak design or a battery that is under-sized or worn out.

.......and for my contribution ...use multicore welding wire! On short runs the weight factor is negligible. Been there got the "T" shirt.

Don't know what "multicore" is referring to . . . but yes, welding wire is an excellent performing product for aircraft fat-wires.

Gentlemen, I thank you for your replies and attention to this. I put the question out here as I was getting many varied answers from other builders as well as Rotax dealers. Lockwood even told me I would be ok with using #6, however, after these informative posts I'm going with a safety margin and ordering #2 cable.

There is NO GOOD REASON to do this. #2 is severe overkill for this application. #4 welding cable is QUITE adequate to the task and easy to work with. #6 would probably work just fine given the short wire runs.

You are going to have to explain your statement on this on:
"??in reality when you lower the voltage going to an electric motor the amp draw drops."
When you lower the voltage AND the motor still runs the AMPERAGE MUST GO UP.
I = E/R
The FIXED is the Resistance. ?The only?variance?in the Resistance is due to Heat and Brush Ware.
At some point in?dropping?the voltage the motor will not function ?- That is because the?voltage is?too low to produce an inductive?field?in the?stator and?rotor.. ?
BUT! ?As long as the voltage is enough to make the motor move the Current ?(I) will go UP.
There is NO OTHER - REALITY - Statement.
I know, I know I'm a PITA and a stickler to detail.

This is a total mis-understanding or mis-representation of motor behaviors.

There are two ?(2) things not known:
1 - When and How the readings were taken to determine the 0.6KW... As I stated in my previous post. ?I betting they were taken AFTER the starter motor reached ?full speed.

Talked about this earlier . . .

2 - You statement of "100% efficient" does not have ANYTHING to do with this. ?Efficiencies equal to OUTPUT divided my INPUT. ?% - IN / OUT. ?And we don't care what the OUT is. ?We are only interested in what the IN is... HOW MUCH INPUT CURRENT will the Starter Motor draw?during?startup.

Depends on where the .6KW number came from. If it's OUTPUT, then EFFICIENCY and LOADS have

everything to do with current draw.

AND - It is the?instantaneous?Current with the high mechanical load that the Wires must handle. AHhhh clamp on meters... That is what I'm betting the the manufacture used to get the current draw.
They show ONLY an RMS value and not the peak. ?Guess-factoring?you can add 29.3% <<<--- a real number, more to that reading to be more in-line with what the wire should be handling. ?And "should be handling'", my quote, does not give a safety margin. A step up of at least one wire size would be minimum.

A total mish-mash of ideas and mis-interpretation of their significance. Yes, the manufacture DOES use a steady state ammeter reading to define motor performance. This is because the power supply and loads are also steady state. Once you bolt it to the engine, total electrical input power is a whole new measurement task.

I designed a starter power meter using a micro-processor and a/d converter that measured instantaneous voltage and current at 10 millisecond intervals and then integrated the power requirement over the duration of the cranking test. One could hook it up, hold the starter for a few seconds and get an instantaneous display of average POWER and total ENERGY used for that cranking interval. But you're right, run-of-the-mill steady state measuring equipment is only one step above useless for evaluating starter system performance.

I really like your idea of a Ground Power Connector, they offer all sorts of advantages. How does being on floats negate the Ground Power Connector?

Don't know why it would. Batteries run down in all airplanes whether on floats, skis or wheels. Also, consider this: I did a second battery installation design for a guy in South America who had a C-206 on floats. His concern was for the occasional situation where he has pushed off from a dock and is now drifting at the mercy of current and/or wind. He was concerned about risks associated with drifting and not being able to get power to the starter. We put a second battery inside one of his floats.

As you know and mentioned, wire run length is a major factor. ?An AWG of 2 should do well for short runs of wire and that #2 does have a safety margin figured in. ?Going to an AWG of 0 for BOTH POSITIVE & NEGATIVE runs should work VERY well.

It will WORK very well . . . but does it meet design goals. Battle ships have weight to burn since over-sized hardware offsets ballast. Not so with airplanes.

AND - Gaggle - I know I posted this before but it REALLY is a GREAT TRICK: SOLDER the wire to the ring lug ONLY at the end next to the mounting part of the ring lug. Crimp First - Then older. ?Clean well.

No foundation for this assertion. See:

http://aeroelectric.com/articles/rules/review.html

"It's true that to achieve the same watt output with a lower voltage you need to up the amperage, in reality when you lower the voltage going to an electric motor the amp draw drops."

Maybe

What I was getting at is that often (VERY OFTEN with high performance modern electrics) you may have a battery and wire size that is very close to asking max. amps that the battery can offer while maintaining a reasonable voltage.

"Often, high performance, modern electrics, very close, max amps, reasonable" . . . all true but non-quantified. Without numbers, you cannot say, "Feature A is better/worst than Feature-B".

Also with electric motors timing is every bit as important as on IC motors. You want to select proper advance for what you are doing. You never want to run a brushed motor retarded from neutral. Amp draw will go way up and brush life and power output way down. Select too much advance for a highly loaded motor and if you can provide enough amps you will get a little more power output, but often the battery/wires net to less power and you are better off running closer to a neutral timing. I wouldn't be too surprised if someone tried a few motors and optimized timing for our 91Xs to get the high output version that draws less amps than the original. I wouldn't be too surprised if the original motor wouldn't benefit a lot by optimized timing, but then again it may not be too easy to adjust.

I've NEVER seen a catalog listing for a motor that speaks to "timing" or more accurately, clocking of the brush holders with respect to the field poles.

When we built motors at Electro-Mech, the customer gives us a design point to which we deliver. If the motor needs to run either direction, then the brushes are always centered. If the motor runs only one direction we MIGHT consider clocking the brushes a tad to improve efficiency . . . large motors are more likely to get compensation windings so that field flux distortion is accurately compensated for all current levels

The exchange cited above demonstrates both the difficulty of defining cranking systems based on performance numbers. It also illustrates the wide range of confusion and mis-information that arises from mis-interpretation of specifications. The bottom line is that starter systems are best selected by a study of recipes for success.