Electric Power and the Experimental Aircraft

RAINBOW Aviation Services™

Having built and flown model aircraft back in the 1960s, we have a fairly decent historical perspective on model aircraft power systems. Watching the transformation in the model industry, from gasoline to electric, got me to thinking. In just a few short years, the model aircraft industry completely evolved and morphed into a sport dominated by electric motors and batteries. Initially, the transformation was simply replacing the gas powered models with electric motors. But the innovation throughout the industry soon overwhelmed convention. The ability for distributive power, thrust vectoring, reverse thrust, and a whole host of other innovations soon proliferated the market with practical flying machines which only a decade ago were things of science fiction. So what was it, in the model aircraft industry, that converted gas powered motors to collectors items at such a dizzying pace? And, if that could happen, what would prevent this from happening across all of aviation?

One of trends in the model aircraft industry was that the initial utilization of electric motors were on the very smallest of aircraft. As battery and motor technology improved, we saw increasingly larger electric motors appear on the scene. It wasn't long and we started to see 16 kW (21.5~ hp) electric motors powering giant scale RC aircraft producing nearly 100 pounds of static thrust proliferate the industry. One of Brian's first ultralights was a Quicksilver model E powered by a 15 hp Yamaha motor turning at 15,000 RPM. We thought if we could fly that Quicksilver with a 15 hp engine, why wouldn't a model aircraft electric motor work just as well? This was going to require some additional investigation. We intuitively understood that the batteries were going to be the primary stumbling block. This necessitated a further analysis of the battery issue with regards to weight versus energy density in comparison to a gasoline powered engine. The calculators came out and we got to work. We searched the Internet up and down, left and right. Even 10 years ago, we found a fairly wide variety of power plant and battery systems with potential. This broad-spectrum analysis laid the foundation for a layman's description that we use on a regular basis which describes the realities of electric power in aviation today.

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For a baseline let's use a Rotax 447, one of the most popular ultralight engines: 40 hp and 34 ft-lb of torque. With a B gearbox and electric starter the total weight is 93 lbs. Compare that to a 40 hp electric motor, say, the German built Nova 30 (Figure: 1). With nearly 60 ft-lbs of torque this motor weighs in at a mere 14 pounds. Add a controller and we are at 20 pounds. This leaves us 73 pounds of batteries added to the equation before we get to the zero fuel weight of the two-stroke Rotax. Granted, based on the installation there may be several other additions necessary to be able to fly both configurations. But for the sake of making our point, we have simplified the analogy. In this configuration, without any gasoline in the 2 stroke configuration, the weight is the same, however, we can fly the electric configuration until we use the energy stored in the 73 pounds of batteries. Whereas in the two-stroke configuration, we are grounded until we add gasoline. When we start adding gasoline, and a few more batteries, we eventually end up with a configuration in equilibrium, where the weight of the power plant installations and the flight times are comparable. Our calculations show that utilizing off-the-shelf, low cost, lithium polymer batteries from the model aircraft industry, will garner us a 23 minute flight time. Less than 23 minutes favors electric power. More than 23 minutes exponentially favors gasoline power.

This made perfect sense. In the model aircraft industry the necessity to fly great distances is nonexistent. The primary mission involves getting into the air, having fun, flying for 10 to 15 minutes, and landing. When you want to fly again, simply replace the battery and start the process all over again. The shorter the flight time, the lower the weight, and the greater the performance. In the human caring side of aviation, this seems extremely impractical. The most common mission is, well, we want to go someplace. While others within the electric aircraft industry currently tout numbers of 45 to 60 minutes as the break-even point, this still doesn't bridge the mission gap. The primary reason for this increase in break-even flight time is simply, battery energy density. Even 15 years ago the break-even point would've been only 12 to 15 minutes. Historically, we now have a lot of data showing that the battery energy density (Wh/kg) has been, and continues to increase the rate of about 5% to 8% per year. Although, the growth rate in individual battery chemistries increase at a much slower and linear rate, the improvements in overall battery energy density is primarily a result of the innovative new chemistries being brought to market every year. If this trend continues, that would suggest energy densities equivalent to gasoline within 50 years. There are many skeptics about this possibility. But let's back up and look at the bigger picture. Most electric motors in aircraft today convert stored energy to usable power and much more efficient rate than gasoline powered engines. During the combustion process the majority of energy stored within gasoline ends up going out the exhaust pipe. The EPA rates gasoline powered vehicle efficiencies at 15% on average, whereas, they rate electric powered vehicles at an average of 60% to 80% efficiency. What this essentially means is that the Holy Grail of battery energy density is about 1/5 the energy density of gasoline. When we hit that milestone an aircraft would be able to fly equally as well, at the same weights, regardless of flight time. However you look at the data, the one universal truth is, the trend continues in favor of electric powered aircraft into the future. With a little bit of analysis, you can't help but get excited about where all of this is heading.

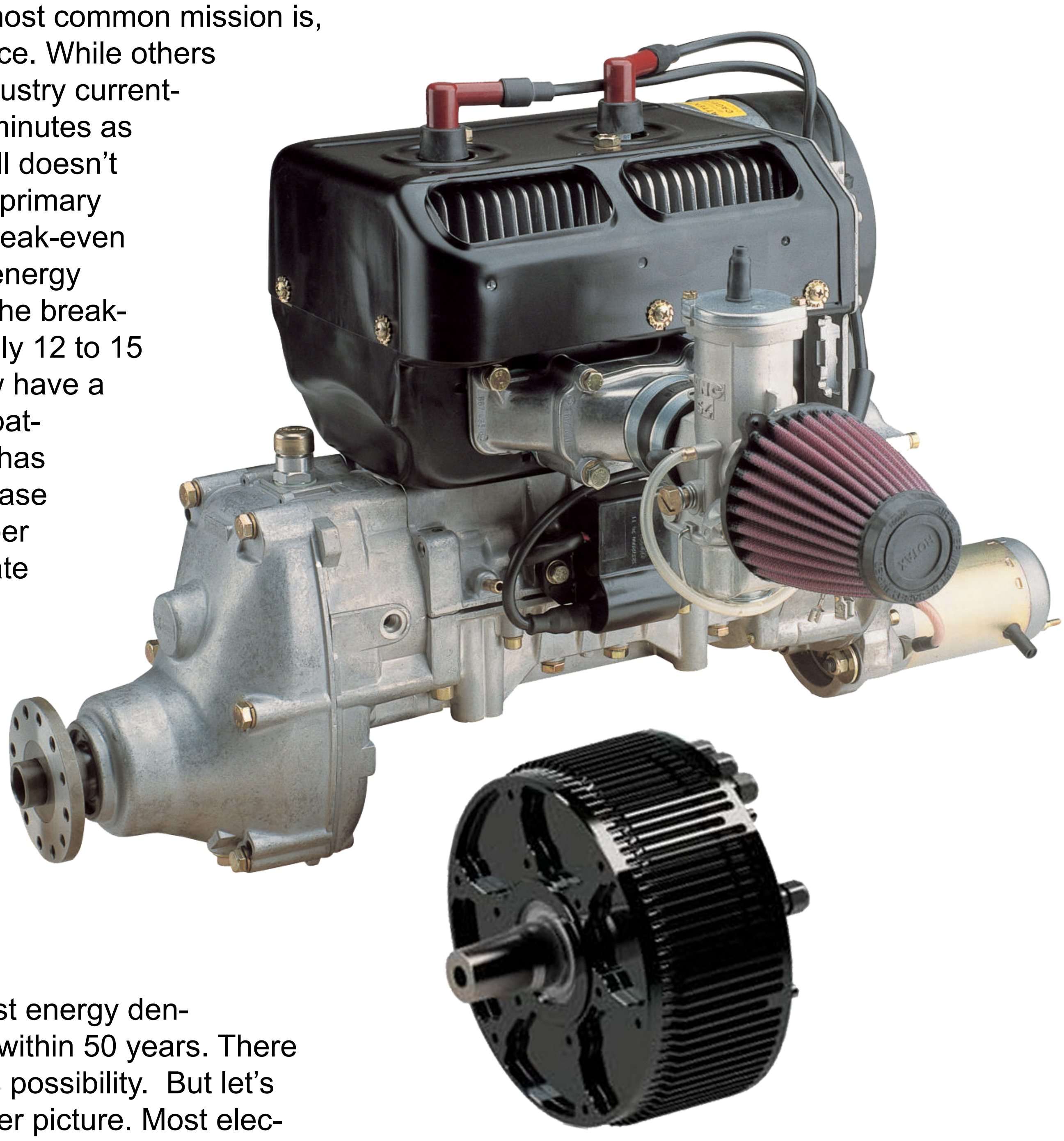

Figure: 1 Two Stroke vs Electric

But back to the more relevant dilemma, the current state of affairs relegating us to this 23 minute flight time paradigm. In the design of the EMG-6 electric motor glider the goal was to leverage these realities and create an aircraft more suited to a mission profile similar to the electric model aircraft paradigm. First, the aircraft would, by necessity, have to be a glider. Airplanes require a 30 minute fuel reserve whereas a glider requires none. Packing around an extra 140 pounds (20% of gross weight) in batteries as dead-weight was ridiculous. A glider, by its nature could take advantage of thermals and ridge lift for its primary lift source, while utilizing the battery for cruise between thermals, or as a sustainer motor in poor lift conditions. In conditions where lift is abundant, we could use regenerative power to recharge the batteries during flight. The ability to be able to use regenerative power, or even thrust reversing to control flight path on approach, would eliminate the necessity for spoilers. Flying locally would allow us to use smaller battery packs, reducing weight, increasing performance and simply changing battery packs in between flights. If we were flying locally, we could simplify the aircraft by concentrating on minimum sink performance rather than glide ratio keeping our design simple and low-cost. Since most of the energy is used up in the climb, having a glider that could be either ground or aero towed to initial starting altitude would allow us to significantly increase the flight time using

Figure: 2 *Author and EMG-6 Electric Motor Glider*

the motor primarily for sustaining flight. As part of our proof of concept of these principles, the original EMG-6 prototype #1 (Figure: 2) was flown over 100 flights using off-the-shelf model airplane technology: motor, controller, propeller, batteries, charging systems, flight data recorders, and instrumentation. We are now on to experimenting with the next generation of electric motors for self-launch capability. Over the last decade while working on this project, we have seen the aviation public perception morph from skepticism to excitement. Every year we see an ever-increasing number of electric powered vehicles including electric powered aircraft.

One of the most exciting aspects of the electric aircraft innovation will come from the ability to leverage the innovation developed in other electric vehicles. Buying electric automobiles and motorcycles from the junkyard, and re-purposing these technologies for utilization in our experimental aircraft. We joke, if you own a Tesla and you see a car on the freeway with the EAA sticker in the window, give them a wide berth. The Tesla batteries are kind of the hot ticket for those of us that are thinking about experimenting with electric systems from the automotive industry. The EAA, out of all the aviation communities, is poised to leverage this technology more than any other segment of aviation. After all, EAA'ers are primarily recreational flyers who love to tinker and innovate. We expect to see a remix within the EAA community similar to the paradigm that is "EAA," started by Paul Poberezny. The entire EAA organization was created by these tinkerers and inventors leveraging other aviation and automotive technologies to build these wonderful things we call home built aircraft.