Scratch Building Electric Powered Foam RC Aircraft

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I think it is safe to say foam has become one of the most important materials for RC aircraft (commercial ARFs & scratch building) because of the ready availability and wide variety and use of low cost electric power. It is much more economical for commercial suppliers of RC ARF aircraft to use foam than labor intensive built up balsa structures. In addition, the price for balsa wood, the traditional RC building material has continued to reach higher levels due to demand in other larger markets and limited supply.

In years past there were only a very limited number of molded foam ARF models available for glow fuel engines. They usually had some internal wood structure anyway to withstand Glo or Gas engine vibration. The most widespread use of foam (commercial and scratch build) was for wing cores that were wood sheeted and/or glassed with fiberglass and epoxy resin.

In the past ten years electric power for RC has evolved dramatically with brushless motors, LiPo batteries, electronic speed controls and 2.4 Spread Spectrum radio equipment in a wide range from micro to large. Alongside this electric power evolution, the available variety of improved foam materials at very reasonable costs has also evolved keeping pace with and supporting the electric power.

I think it is also safe to say that presently few newcomers in RC build balsa kits. The typical extent of building electric models is now assembling already built up parts of mostly (or all) foam and some balsa and light ply in an ARF kit. Scratch building electric powered aircraft now can be done relatively inexpensive and quickly using mostly foam materials. The benefits are similar to building balsa kits in previous times. It helps develop building skills and knowledge of the materials, adhesives, finishing, etc. Also helps learn various aircraft design features and terminology. And last but not least the self satisfaction of taking an idea and making it yourself and seeing it fly.

This presentation is primarily about what and how I scratch build foam electric RC models. There are online websites such as FlitecTest.com that are very good with lots of information and videos of techniques they use. Also you can Google "Noob Tube" (or Experimental Airlines) for

some good foam building information. I certainly recommend you take a look at those. After a review you can decide what you like and give one or all a try. Important thing is to jump in and try some things and have some fun.

1). Foam types available for scratch building:

EPS / Expanded Polystyrene beads (ice chests, cups, packaging, etc)

XPS / Extruded Polystyrene sheet (foam board core and other foam sheet applications)

XPS / Extruded polystyrene (blue and pink home insulation foam sheets)

EPO / Expanded Polyolefin beads

EPP / Expanded Polypropylene beads

DEPRON - Depron is actually polystyrene (EPS/XPS) plastic and the (EPS) means expanded while (XPS) means extruded. For our purposes, we're only interested in the stronger, denser XPS Depron which also happens to be closed-cell foam.

2). Examples of various foam types :

Paper covered XPS foam display board – Dollar Tree foam
Paper covered XPS foam Tri-fold display board (Pat Cataan's, other Craft stores
--- Paper covered is more stiff
--- Paper covered is heavier (usually doubles the weight of a sheet of foam)
--- Paper covered is more prone to warping but laminating pieces and a couple dusting coats of clear spray paint (Rustoleum) usually prevents any problem. On-line videos showing techniques for folding paper covered foam sheet to make an airfoil shape wing also eliminates any problem with warping
--- EPO and EPP samples--- Owens Corning (pink) and Dow (blue) XPS samples

3). Examples of foam scratch built RC aircraft :

(A). Simplest are flat foam models :

Micro Extra
Micro Wing
Honda SU 26
Gee Bee R3
Shuttle-X
Paper Airplane
Fighter Combat

(B). A variation of the flat airfoil is the "KF" type airfoil which is a kind of simulated airfoil that provides some improvement over just the flat sheet wing. Another gain is that the laminated foam pieces are much stiffer eliminating the need for a carbon fiber wing tube.

Flying Wing with KF airfoil
Slice 3D with KF airfoil
Sequence 3D with KF airfoil

(C). Bit more complex is combo of flat fuselage with airfoil wing or an airfoil flying wing :

Slice & Dice
Slice Flying Wing
Hurr-E-cane flying wing
Scan Eagle

4). Construction :

Fuselage types :

-- Flat
-- Flat X
-- 3 dimensional

Wing types :

-- Flat
-- Flat with KF airfoil (previously discussed)
-- Airfoil (by hot wire cutting method)
-- Airfoil by folding over flat foam sheet

Cutting Foam sheet :

-- Must use a **new** Xacto #11 blade

Cutting foam blocks and thick foam sheets :

-- Xacto Razor Saw
-- Hacksaw (results in rough cut edges that must be sanded to final dimensions so a bit of extra material must be allowed for
-- Hot Wire

Finish of foam edges by sanding :

-- Use a good sanding block like the PERMA-GRIT
-- Use sanding sticks (professional type nail files)
-- After sanding apply thin layer of Elmer's glue on the edge to help keep the paper edges tacked down.

Preparation of paper covered foam sheets :

The paper covered foam needs to be moisture proofed otherwise when landing in damp grass the paper will get wet and tend to loosen and warp. In the past I have used Minwax Polycrylic spray (Satin) on Tri-Fold display board from Pat Cataan's (and other Craft stores) with some success but it was tricky and bit inconsistent to light dust coat the foam pieces and not have them want to warp slightly. This was even with the precaution of spraying both sides one after the other. This is due to the Polycrylic being water based that causes the paper to expand ever so slightly. Another issue found was using the Polycrylic on the Dollar Tree foam tends to degrade the paper's bonding to the foam as well has tendency to cause warping. Recently I found that two to three light dusting coats of Rustoleum clear spray on the Dollar Tree foam sheet works best. Spray at a distance of about 10". The non-water based Rustoleum clear appears to enhance the paper bonding to the foam based on a limited number of test samples. The Rustoleum clear will also work on the other paper covered foam sheets and has become my favorite and is recommended. I spray the parts after they are cut out and laminated doing both sides one after the other. Try to avoid getting the Rustoleum clear on the foam sheet edges because it can attack the exposed foam. A thin layer of Elmer's white glue can be applied on the foam sheet edges before spraying to prevent any interaction and this helps to keep the paper edges tacked down.

Gluing of parts :

-- 3M-77 spray adhesive can be used to laminate paper covered foam part
-- Use Foam Safe CA for all polystyrene based foam
-- Regular CA is preferred on EPO and EPP foams but Foam Safe can be used
-- Epoxy, white glue (Elmer's) can be used on all foams

Equipment mounting :

-- 1/8" plywood is usually adequate for motors in the 28mm to 35mm (and smaller) range. Add side supports to the ply mounting plate if the edges overhang.
-- 1/64" plywood is recommended as underlayment directly to flat foam sheeting for mounting servos, speed controls, receivers and especially the Velcro strip for main battery. This requires carefully cutting just barely through the paper and removing it for an area the size of the 1/64" ply piece.
-- 3M Extreme Mounting Tape (thin black sponge like) is good for small servos,receiver and speed control mounting.
-- Hot glue can also be used if preferred for attaching parts like servos

5). Finishing :

Painting :

Water based Acrylic craft paint can be applied directly to all non-paper covered foam. It is inexpensive and available in a large selection of colors including bright Neons. For molded EPO and EPP, it is recommended to clean off the surface with rubbing alcohol first. It may be necessary to lightly sand the surface, only the area to be painted with 600 grit paper. It can also be used on paper covered foam that has had Rustolem clear spray prep however, test on a

spare piece first that has been sprayed with clear. The Acrylic is available at craft stores like Michael's and Pat Cataan's and Walmart.

Rustoleum color spray paint can be applied directly to EPO and EPP by using two to three very light coats. A thick coat will usually attack the foam. I have not tried colored Rustoleum on paper covered foam sheet. Probably ok if applied in very light coats.

Colored Tape (sometimes referred to as Zagi tape) :

This is the best method to add some color to paper covered foam sheet, especially that from Dollar Tree, with no possible effect to the paper adherence to the foam. Available colors are red, yellow, orange, dark blue, purple, green & black. Sources include HobbyKing.com., RCfoam.com and other online RC suppliers. "Parchment Paper" (typically placed on a cookie baking sheet as a non stick surface) can be used as a temporarily holding place for a piece of colored tape to facilitate trimming in some manner before applying it to the model.

Epoxy Resin :

Can be used for sealing and adding strength / stiffening, especially with wing airfoil cores cut from EPS (styrofoam) blocks. However, it will add weight, easily one to two ounces and more based on surface area being coated. This extra weight has to be considered in the overall design. Typically 24 grams will cover about 230 square inch surface area (about 1.5 square foot). Materials include Bob Smith Finishing Resin and CST (The Composite Store) epoxy resin and hardeners. A combination of Fiberglass cloth and epoxy resin coating can be applied for the ultimate tough finish.

6). Some basic design considerations for scratch building:

Choosing a model---

A. Pick an existing aircraft / model type & shape you like and find dimensional information and/or photo views on the Internet and then scale up (or down) to arrive at the dimensions for the desired model size. Using the scaled dimensions, then create line drawing outlines of the fuselage, wing and vertical and horizontal stabilizers.

B. Look for line drawing plans on the Internet of a desired design and use as is or modify. There are several websites that offer free plans for downloading.

C. Make a useable full size layout of your own concept.

D. If a flying wing is preferred and you are not familiar with the design considerations then just copy an existing design layout to recreate it in flat foam sheet and KF airfoil. Scale it up or down in size as desired. Sweep angle is good between 27 and 32 degrees. Use the Flying Wing CG calculator at the Internet link provided below.

E. Overall the TLAR (that looks about right) method can be used for most foam RC aircraft.

Determining CG (center of gravity) :

If not based on an existing design with CG information already established, then calculate the proposed design layout CG. If the wing is a simple constant chord design use a distant of 25% back from the leading edge as a good starting point.

If the wing is a swept back or tapered design then there are basic, easy to use CG calculators on the Internet.

Links to CG calculators ---

http://www.friendlyflyers.org/cg-calc.html

The following CG calculator is primarily for flying wings but can be used for normal aircraft. I like it because it generates a line view of the wing layout confirming the data you input. For flying wing CG calcs use the more conservative 20% default value for CG instead of the usual 25%. The wings typically fly more stable in fast tight turning if just slightly nose heavy.

http://fwcg.3dzone.dk

Basic stability considerations :

If the design is not dimensionally or proportionally based on an existing one, then some consideration should be given to basic lateral stability (sometimes referred to as rudder moment arm). The ratio of the distance from the back edge of the prop to the CG to the distance from the back edge of the prop to the rudder hinge line should be in range of 0.28 to 0.34. Typical is 0.30 - 0.32. Lower value results in longer tail moment and more stable better tracking. Higher value results in shorter tail moment, less stable and more snappy maneuvers. Other considerations are the vertical stabilizer area (includes rudder and fuselage area below the vertical stab and rudder) in range of 10 to 12% of the wing area should be adequate for most electric powered foam RC aircraft. Another stability consideration referred to as “Static Margin” regards horizontal stabilizer (including elevator) area and placement. Some online CG calculators include Static Margin calculations. Here is a link to one of those.

CG and Static Margin calculator---

http://adamone.rchomepage.com/cg_calc.htm

7). Choosing a power system :

There is an existing extensive report at the Mon Valley RC website about electric motors. The basic considerations are watts (power) per pound of model and KV

Here is link to MVRC report---

Electric Motor Basics---
http://www.monvalleyrc.com/images/Howto/Electric%20Motor%20Selection%20Basics%20R2.pdf

The following list of motors and speed controls are adequate for most foamies. The stated weights are total ready to fly aircraft plus LiPo battery.

For Sport Aircaft up to 28 oz with wingspans of 36" to 48" and 3D aircraft up to 20 oz with wingspans of 36" to 44". Use 3s 1300mah or 2200mah Lipo as appropriate with 30 amp ESC. ---

1. A2217-8 1100kv, about 170 watts, 10x4.7 to 11x7 Slo-fly prop, $24.95
http://www.bphobbies.com/view.asp?id=V450327&pid=B3945418

2. D2830-11 1000kv, about 200 watts, 10x4.7 to 11x7 Slo-fly prop, $10.29
http://hobbyking.com/hobbyking/store/__12921__D2830_11_1000kv_Brushless_Motor.html

For Sport aircraft up to 20 ounces and 3D up to 14 ounces with wingspans 30" to 36". Use 3s 800 to 1300mah Lipo with 20amp ESC. ---

1. About 120 watt, 1000kv, 10x4.7 prop $12
http://www.valuehobby.com/power-systems/brushless-motors/outrunner-airplane/e400-2212-1000kv-outrunner.html

2. About 120 watt, 1250kv, 9x4.7 to 10x4.7 prop, $12
http://www.valuehobby.com/power-systems/brushless-motors/outrunner-airplane/e400-2212-1250kv-outrunner.html

3. Bell type motor, about 120 watt, 1250kv, 9x4.7 to 10x4.7 prop, $7.45
http://www.valuehobby.com/power-systems/brushless-motors/outrunner-airplane/emax-cf2822-outrunner.html

For Flying Wings 30" to 34" and 14 ounces max --

1. Exceed Rocket 2205 2300kv, 135w, 6x4 APC prop, $8.95. Use 3s 800mah to 1300mah Lipo and 20 amp ESC---
http://www.nitroplanes.com/86ma03-2205-2300kv.html

For Flying Wings 34" to 48" and 14 to 22 oz.---

1. Hobbyking D2826-6 2200kv, 342w, 6x4 APC prop, $10.21. Use 3s 1300mah Lipo up to 34" wing and 2200mah Lipo for 44" to 48". 30amp ESC (with 1300mah) or 40amp ESC (with 2200mah)---
http://www.hobbyking.com/hobbyking/store/__12919__D2826_6_2200kv_Outrunner_Motor.html

Low cost Speed Controls that can be programmed with a low cost Hobby Wing program card ---

1. 20amp
http://www.valuehobby.com/power-systems/speed-controller/airplane-heli-esc/hobbywing-skywalker-20a.html

2. 30amp
http://www.valuehobby.com/power-systems/speed-controller/airplane-heli-esc/hobbywing-flyfun-30a.html

3. 30amp
http://www.valuehobby.com/power-systems/speed-controller/airplane-heli-esc/mystery-30a-esc.html

4. 40amp
http://www.valuehobby.com/power-systems/speed-controller/airplane-heli-esc/hobbywing-skywalker-40a.html

ESC Hobby Wing program card, $7.99---
http://www.valuehobby.com/power-systems/speed-controller/esc-programming-card/hobbywing-flyfun-skywalker-program-card.html

Some examples of foam electric powered RC aircraft presented :