DE HAVILLAND DH90 DRAGONFLY
by Ivan Pettigrew
Construction Notes

De Havilland built four multi engine biplanes in the nineteen thirties and the Dragonfly was the last of this series. The first was the DH 84 Dragon which used two four cylinder 130 HP Gypsy Major inline inverted engines. These engines were built by a division of the De Havilland Company, and used in many of the "Moth" series of single engine planes built by De Havilland during that era. The DH 86 Express was a four engine biplane that used Gypsy Six engines. These were also built by De Havilland. The same cylinders and pistons were used as in the Gypsy Major engine, but a longer crankcase was built to make it a six cylinder engine giving 200 H.P. The DH 89 Rapide was the third multi engine biplane and used two six cylinder Gypsy Queen engines, later versions of the Gypsy Six. Having tapered wings and more horse power than the DH 84 Dragon, the Rapide was much faster. More Rapides were built than all the other D.H. multi engine biplanes combined. The last multi biplane was the Dragonfly. It was in some ways like a scaled down Rapide. It used the four cylinder Gypsy Major engines and carried four passengers in addition to the pilot. Sixty eight Dragonflys were built, starting in 1935. Two are still flying today, G-AEDU in England with a red fuselage and engine nacelles. The wings and tail are silver. ZK-AYR in New Zealand is blue and silver. G-AEDU has the possible distinction of being the oldest plane to fly the Atlantic. In 1995 it flew from the UK to Oshkosh, and the following year marked its sixtieth anniversary making the return flight to England. For the purist, it should be noted that in the process of being rebuilt, the British G-AEDU has had one of its windows filled in. It is the small triangular one just behind the windshield on the starboard side.

Unlike earlier DH biplanes, the Dragonfly had a longer top wing than lower one. Ailerons were only fitted on the top wing. Notice that the centre section of the bottom wing has a thicker airfoil than the outer panels. The thicker wing section added strength to this critical area which carries the stress of the undercarriage, and also provided more space for the fuel tanks in the full scale plane.

FUSELAGE

In most construction, regular carpenter glue has been found to be the most satisfactory adhesive to use. It gives time to set the parts in the correct position, and when building a box structure as used in a fuselage like this, carpenter glue is much stronger than CA glues for attaching crosspieces where the end grain is being glued. The primary section of the fuselage of the Dragonfly is of traditional "box" construction. The two sides of this structure are built over the shaded sticks shown on the plan, and then joined together. Notice that the cockpit area is detachable to give access to the motor batteries. It is best built last, when the rest of the fuselage has been completed. The top and bottom bulkheads are added to the crosspieces in the primary box section of the fuselage, then sheeting is applied where shown. Aft of the trailing edges of the wings, the square section of the fuselage transitions to having a rounded top and bottom. The radius of the curve at the corners is very small in the first two bays behind the wing. Instead of sheeting these sections, on option is to fill in with solid balsa shaped to fit. Other additions are the doublers that add strength inside the wing saddles, and the stringers inside the fuselage sides that support the cross pieces which hold the servo mounts. The platform for the motor battery is shown. This is longer than required, but provides for movement of the battery in order to achieve the correct C of G location. The exact location of the battery will depend on several factors such as the weight of the battery and motors used, and also the weight of the tail. Be careful not to overbuild the tail surfaces. With a long moment arm, weight of the tail surfaces is critical. The removable cockpit area can be built in place, pinned to the fuselage to get a good fit. It should be separated with very thin plastic sheeting like saran wrap so that the cockpit section does not get glued to the fuselage. The lower horizontal section of the removable cockpit section has a compound curve. To get a good fit, it is best to carve this from an oversize balsa stick.

The tail cone is built up from scrap balsa and cannot be completed until the tail surfaces are attached.

TAIL SECTION

Notice that the spars for the stabilizer and fin are tapered, being quite wide at the root in order to give added strength. Having a relatively thick cross section like this means that the construction can be very light, but remains strong. Start construction by first making the spars and fitting the hinges. Build the surfaces over the plan in the conventional manner. Although the stabilizer spar is built in one piece, it is necessary to build just half of the stab at a time. After building the first half, prop the tip up a little so that the bottom surface of the spar on the other half is flat on the building board. There is one thing to watch however. Because the spars and ribs are tapered, if the tail units are built with the lower surfaces pinned right down to the building board, they will end up with a warp in them. Check this during assembly because it may be necessary to slide some of the parts up the pins slightly so that no warp is built into the surface. The section that has to be slid up the pin the most is the tip of the leading or trailing edge where is joins the last rib. Tail surfaces built in this manner with a deep chord are resistant to twisting. Do not rely on the shrinkage of the covering to reset the surface if it has been build with a warp in it. If a tail surface is warped, dampen the structure and weight it down while drying overnight. A couple of attempts at getting it straight may be necessary

The horizontal stabilizer is held in place by inserting it into the tapered slot formed in the construction of the fuselage sides. It must be glued in place before the fin is attached. The spar of the fin continues down to the bottom of the elevator. To give it maximum strength, the base of the fin spar should be glued to the beams on the side of the fuselage that support the elevator. A shim or wedge may be necessary to close any gap between them. The rudder should not be attached to the fin until the wire connecting it to the tail wheel has been installed. This step requires some De Havilland ingenuity. It helps to have built a Mosquito or Chipmunk.   Both use a similar arrangement, but that streamlined tail cone was pioneered by the Dragonfly. After bending the tail wheel wire to shape, insert it from the bottom, threading it through the rudder control horn which is made of brass sheet. It can be soldered to the wire arm when everything is in place. It may be necessary to leave the top end of the wire straight until it is in place, then make the 90 degree bend at the top after it has been installed. The final step is sliding the rudder on to the hinges and the wire steering arm. If using nyrods, be certain to brace them well at the stations along the fuselage so there is no "bowing." Check that there is clearance for the full movement of the tail surfaces without the trailing edges clashing with adjacent surfaces.

WING CONSTRUCTION

Upper wing. The top wing is the easier one to build because the spar is straight all the way from the centre of the wing to the tip. Cut the main spar for the top wing from 3/32 inch sheet balsa. Glue spruce strips to the top and bottom edges of the wing spar as shown in the plan. If spruce is not available for these strips, bass or other softwoods that are stronger than balsa would be suitable. Join together over the plan so that the sweep back and dihedral angle are correct. This joint is very important both for accuracy and strength. The spar must be held perpendicular to the building board while measuring the dihedral angle or it will not be correct.   Tapered spruce or basswood doublers must overlap the joins in these strips at the centre line.

Before cutting out the ribs, notice that they are of different thicknesses, depending on the stress they are subject to. Basically all ribs are cut from 1/16 inch sheet unless otherwise indicated. It is good to cut ribs first to the outside line shown on the plan. Where there are ailerons in the upper wing, cut the ribs full length as if the wing is being built without ailerons. After cutting the ribs out, nest them together to check accuracy and sand off high spots. Cut all the ribs into two pieces at the point where they will be glued to the spar. Trim 1/16" off the top and bottom edge of nose ribs to allow for the sheet covering between the main spar and leading edge. A balsa stripper set to 1/16" makes this very easy to do. Aft of the main spar, trim 1/16 inch from the edge of the ribs where sheeting is inset, such as at the wing centre section, and where the plates are located that hold the strut mounts in place for securing the interplane wing struts.

Assemble half of the upper wing (e.g. left half) flat on the workbench with the other half of the spar blocked up a little to give the correct dihedral angle. Start by pinning the spar in place on the plan, but use 1/16 inch shims to keep it a little clear of the building board. This allows for the thickness of the sheeting that will be attached to the bottom of the spar. Attach the rear section of the ribs to the rear face of the main spar. Next glue all of the trailing edge in place as if the wing is to be built without ailerons. They will be cut out later. Now attach the nose ribs to the front surface of the spar, making sure that a space of 1/16 inch is left at the bottom of each rib to allow for the sheeting on the lower surface. At this point the 1/8 inch inner strip of the leading edge can be attached to the front of the ribs. The wings tips can now be built. When this half of the wing panel is complete, block up the tip so that the spar of the other half is flat on the workbench, and assemble the second half of the wing.

Sheeting is now applied from the leading edge to the main spar, but ONLY to the lower surface of the wing. It will be noted that the wing at this point is still not torsionally strong, meaning that it can easily be twisted. After the sheeting is applied to the upper surface of the area already sheeted, the wing will be very rigid and difficult to twist. Hence it is very important to weight each wing panel down on a surface that is perfectly flat while applying the sheeting to the top surface. There is no washout in the inner part of the wing. It only starts from the point where the ailerons start. When the wing is weighted down with a 3/16 inch block under the trailing edge at the tip to give the correct washout to the outer section, apply sheet covering to the top of the wing from the leading edge to the spar. After applying this sheeting to the top surface, the remaining leading edge strip is cut from ¼ inch sheet balsa and glued to the 1/8 inch strip already in place. It is then contoured to shape. Notice that this outer strip does not pass through the area of the center section where the wing joins the fuselage. A sharp pointed leading edge on a wing makes for a sudden stall. That does not hurt in the inboard section of a wing, but should be avoided out towards the tips. The leading edge of the outer section of each wing should be well sanded to give a blunt rounded curve. Check that there is no twist in the wings except for the wash out, and that each side has the same angle of incidence. If there is any undesired warp in the wing, it is important to correct it at this stage before it is covered. Dampen the sheeting between the spar and leading edge, and weight the wing down overnight so that it sets without any twist.

AILERONS

The aileron design used in this model is known as "Frise." It is important to duplicate this design. It makes for good control balance at slow speed and helps avoid the adverse yaw that is often a problem in slow flying models with a long wingspan. If built correctly, the forward point at the lower edge of the aileron spar should protrude downwards into the airstream to give some drag when the aileron is raised such as when entering a turn.. This drag on the inner wing helps the aircraft turn in the desired direction. It greatly reduces the bad effects of adverse yaw that results from poor aileron design. Frise ailerons are a little more difficult to build than simpler styles, but the effort to build them correctly adds much to the good flying characteristics of any model. To complete the ailerons, insert the secondary spars in the top and bottom surfaces of the wing where the ailerons will be attached. Make a diagonal cut in each rib where the aileron will be separated. Also cut through the trailing edge at the end point of each aileron so that is can be removed. A strip of 1/16 inch sheet balsa is now attached to the rear surfaces of the secondary spars and ribs where they were cut.

To get a good fit for the ailerons, they are best built in place. Cut a piece of 1/8 balsa that will form the leading edge (spar) of the aileron and hinge it in place to the upper secondary spar. It may be best to make this strip a little wider than estimated, and later trim to the right width so that it matches up with the surfaces of the wing. If the wood of the secondary spars is on the flimsy side where the aileron hinges are inserted, add a small doubler to the front of the spar. Be sure to pin the aileron hinges with toothpicks. This is done after the tongue of the hinge is inserted in the balsa slot by drilling a 1/16" hole in the middle of the tongue area. Then push a toothpick through and apply a drop of glue. Cut off the ends of the tooth pick. Pinning the hinges this way will ensure that they don't come lose. "Hinge gap" covering on the top surface of the wing will further ensure that hinges do not come out.

Now the aileron trailing edge with attached ribs is glued to the 1/8' spar that forms the leading edge of the aileron. It helps to pin this leading edge securely in place to provide the correct angle. A good option is to cut two or three small triangles and temporarily glue them between the two surfaces that are hinged together. The ribs that are attached to the trailing edge of the aileron will need to be trimmed to allow the aileron to match up with the 1/8 inch balsa spar. An additional rib has to be made for the end of each aileron. Notice that these end ribs are made from thicker wood to withstand the stress resulting from shrinkage of the covering material. The trailing edge is slightly tapered from rib #10 to the tip. When this strip is cut off, it leaves a flat surface on the rear edge of the aileron. The bottom surface of the aileron should be trimmed in this area so that the trailing edge is reflexed slightly and comes to a point where it meets the upper surface. It adds a little washout effect and makes the tip less prone to tip stall.

Aileron differential is the other thing that helps to counter adverse drag, so it is important to angle the arm of the aileron servo forward as shown on the plan. The distance the aileron horn is back from the leading edge of the aileron is another factor in aileron differential, so watch that the aileron horns are mounted where shown on the plan. Placing the aileron horn slightly further back will increase the differential.

BOTTOM WING

The lower wing is built in one piece, but has to be done in three stages. Construction is similar to the top wing, but the centre section which extends out to Rib #2 is flat and not tapered. First build the spar which has two compound joins where the dihedral and sweep back both start. Again it is very important to get these angles correct. First build the central section directly over the plan on the building board. Then block up one end of the completed section so that the spar of the outer panel at the opposite end is flat on the building board while it is being built. Next build the other outer panel in a similar way. It is best to build all three sections before sheeting is started. Proceed with the sheeting as for the top wing, but it is wise to install the wiring for the motors before applying the leading edge sheeting to the top surface of the central section. Note that the outer leading edge strip does no pass through the area of the engine nacelles, so it is best left until the nacelles have been built. Extra sheeting aft of the spar is applied to the wing in areas where the engine nacelles are located and should be inset. This sheeting is necessary to support the nacelles and also the adjoining wing covering material, so should extend beyond the edge of the nacelles. Washout is the same for the bottom wing as the top one. There is no twist as far out as rib B5, but a gradual twist throughout the outer panel to give 3/16 inch washout at the tip, this being measured at the trailing edge at the last rib location.

ENGINE NACELLES, MOTOR MOUNTS AND UNDERCARRIAGE

The engine nacelles are built by first gluing the ¼ inch spruce beams (P1) in place, securing them firmly to the lower surface of the wing and the main spar. Then the pedestal that supports the undercarriage is built. Cut the beams P2, P3 and P4 from ¼ x 1/8 inch spruce and glue them in place on the triangular piece of 1/16 inch ply where the ends all come together. These joints must be of good quality. Using carpenter glue and clamping the joints will be sufficient. One of these assemblies is now glued to each outer surface of the first beams, (P1). See front view of the pedestal. Again, the joints should be clamped. Where the top end of P3 meets up with the leading edge of the wing, a thick gusset (not shown on the plan) should be glued on the inner face of the P3 to strengthen the attachment to the leading edge. The 1/8 inch plywood plates (1½ x 1 inch) that the undercarriage legs are attached to are now glued in place at the bottom end of P2. Epoxy can be used for these attachments if it is not possible to clamp them well with carpenter glue. Now glue the triangular pieces of ¼ inch sheet balsa to the top surfaces of P1 at the front where the motor mounts will be attached. The 1½ x 1½ inch squares of 1/8 ply that form the motor mounts are now glued in place on the front of these assembly. Adjustments may have to be made to accommodate motors of a different size.

The undercarriage is designed so that the lateral section of the U/C leg that passes through the two nylon mounting clamps serves as a torsion bar. The swept back nature of the U/C leg means that the wheels arc both backwards and upwards when a bump is hit. This results in very good absorption of bumps when operating from a rough surface. Complete the construction and mounting of the undercarriage legs.

Next the nacelle bulkheads are glued in place. Start by gluing cross pieces of ¼ inch square balsa 2¼ inches long under the "P1" beams just ahead of the leading edge of the wing. The ¼ inch bulkheads (N1) are then attached to these cross pieces. Glue N-3 bulkheads in place supported by a thin cross piece where they are glued to the "P1" beams. After this, N-4 is attached to the bottom of N-1 and N-3, then a curved strip of 1/8 sheet balsa is attached between the rear point of N4 and the trailing edge of the wing. This serves as a keel for the trailing edge of the nacelle. The nacelles are now planked with 1/16" sheet balsa. Notice that bulkheads N-1 at the front of the engine nacelles are cut from ¼" balsa, but the planking of the nacelle just comes to the mid point of that bulkhead. This leaves a 1/8 inch shoulder at the front of this bulkhead which serves for holding the cowling in place. When the planking is completed the motors should be installed. After fitting the motors, check that they are all perfectly aligned. Use shims to make any fine adjustments that may be necessary.

The engine cowlings are built in place with the motors installed. Each cowling will be held in place by two screws at the aft end of the cowling, abeam the “P1” bearers. These screws do not hold well if screwed into the 1/8” shoulder of the balsa bulkhead. So two short strips of 3/16 inch square spruce should be glued to the front face of “N1” at that outer edge (at the level of P1) so that the mounting screws go into these blocks and hold well.

Next the nose blocks are made, but the hole for the propeller shaft should at this point be made just large enough for the nose block to be a snug fit over motor. This will hold the nose blocks in place while the cowlings are built. Afterward the cowlings are completed the hole for motor clearance can be enlarged. With the nose blocks held in place on the motor, start making the cowls by cutting out the side panels of each cowling. These are glued at the front edge to the nose block, but only attached to the “N1” bulkhead by the #2 screws at the rear edge. Next apply the top curved sections of the cowling, gluing these to the nose block and adjacent side panels, but not of course to N-1. The curved sheets forming the top of the cowling are easily shaped if the outer surface is moistened. Attach these to the upper edge of the side panels by having doublers of 1/16 x 1/8 balsa along the inside of the joins. The bottom of the cowlings, (“C2” are now shaped and glued to the nose block and lower edge of the side pieces, but not of course to “N1.”) When the glue is dry, take out the screws and remove the cowlings. Now the hole in the nose block for the motor can be enlarged to give adequate clearance. Before covering the cowlings, small washers should be made from 1/64 ply and placed under the heads of the #2 screws that hold the cowlings in place. These ply washers are glued to the sheet covering.

The plans show the motor mount designed for the commonly used outrunner brushless motors. However, the prototype model used geared inrunner motors, so any pictures shown of the motor installation will be different for this reason.

The wheel fairings are each held in place with two screws. They can be built in place so as to ensure a good fit and provide clearance for the undercarriage legs and wheels. Cut out F1 and screw in place at this point with just the rear retaining screw and a pin at the front. Separate it from the nacelle and cowling with a piece of saran wrap to that the sections are not glued together. As in other applications, blocks of spruce or ply should be glued to the inside surface of “C2” and “N4” so that the screws are held firmly. F2 and the wheel wheel fairing side panels of 1/16 inch sheet are now attached to F1. The nose piece of the wheel fairings is made at this point with a single thickness of 1/16 balsa and attached with the grain running vertically. The joins between the nose section of the fairings and the side panels should be reinforced with doublers on the inside. Then laminate the nose section with a second smaller piece of 1/16” sheet glued to the inside in order to increase strength. Be sure to allow clearance for the rearward movement of the U/C legs so that the wheels do not hit F-2 when the model hits a bump and the gear legs flex backwards. The mounting lug at the front of the fairing is now attached with epoxy and the front screw inserted.

The wing struts are constructed as shown on the plan. Where necessary, 1/16 sheet balsa plates are glued between adjacent ribs to provide for attaching the strut mounts. Small rare earth magnets inserted into these tabs as shown will keep the wire at the end of the strut from coming out. The struts are not functional, so can be built from balsa. Two methods are used to attach the wire ends. Where the wire end is straight, such as at the bottom end of the inner struts, a hole is drilled in the bottom end of the strut and a straight piece of wire is inserted. If a drop of CA glue is put in the hole first, the wire sets up firmly and is not likely to come out. For the other fittings, the wire is fitted into a shallow slot cut in the side of the strut. Strength is improved if the end of the wire is bent to a right angle and inserted into a hole drilled through the strut where the end of the wire is to be located. After the wire is glued in place, it can be bound with a few turns of thread. The struts are covered with film covering, using the same film as used for covering the airframe. The exact location of the bottom ends of the inner struts where they are inserted into the engine nacelles is shown on the plan. When assembling the model, attach the lower wing first, then fit the inner struts into the engine nacelles before attaching the top wing.

Covering is conventional with Solar film, Monokote or other films of a similar nature. Clear transparent MonoKote is great for covering all the windows. It is best to do these first, before applying the rest of the covering on the fuselage.

Very little needs to be said about flying. If the wings are built as indicated, and have the correct washout, there should be no danger of tip stall. Unlike the full scale aircraft, the model is easy to keep straight on take off, and slow three point landings are easy to do without the use of the optional flaps. In the full scale plane, wheel landings were "mandatory." With the model it is better to do wheel landing if using flap, but this is subject to the pilot's preference.

Good Luck with your Dragonfly

SUMMARY

DH 90 Dragonfly. 2012. Scale 1/7 Span, upper wing , 74 inches. Lower wing, 66 inches. Wing area 1,026 square inches. (80% biplane equivalent is 820 sq.ins.) Primary airfoil; Selig 3010 modified towards the tips. Length 54 inches, Flying weight 78 ounces. Wing loading is 13.7 ounces / square foot (allowing for 80% efficiency of biplane wings.) Motors, brushless Park 400 or 450 outrunners, or equivalent. Battery, one 3S 3.0 AH li-po. With brushless motors, each motor requires its own ESC, but these can both be run parallel from one battery. Recommended for this set up would be one 3S-2600 mAH Li-Po, or slightly larger for extra long flights or to add weight up front for balance. If the speed controls are fitted with BEC, be sure to disable the BEC in one of the speed controls as per instructions; cutting the red wire.

Flight efficiency in this design comes with the high aspect ratio tapered wings, and use of the thin Selig 3010 airfoil. But as in sailplanes, thin wings make for a challenge in accurate construction. Likewise, the undercarriage is a tight fit in the slim nacelles and wheel fairings, but these add to the streamlining of the model. The torsion bar suspension used on the main gear provides for good operation on rough fields. Flight characteristics are excellent. The prototype is fitted with a split flap as used in the full scale plane. It adds drag, and helps in making a steeper approach, but this kind of flap does not add much lift. The flaps are not normally used for takeoff. Smooth three point landings are easier without flap because the stall is no so abrupt. Aerobatics are not a scale manoeuvre for the Dragonfly, but if you want the occasional change from scale-like flying, the model is quite capable of doing very large graceful loops, stall turns and Cuban eights. Rolls are on the slow side but can be done. Spins depend on the C of G location and tail surface throws. The interplane wing struts are held in place with small rare earth magnets, so assembly at the field is fast. It is a robust model that can be thrown about and enjoyed.

For Model Airplane Magazine report, check http://www.modelairplanenews.com/blog/2014/07/22/homebuilt-project-construction-article-extras-de-havilland-dh90-dragonfly/