PEAK OF FLIGHT NEWSLETTER

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Designing and Constructing Fins for Low-Power Rockets

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PEAK OF FLIGHT

Designing and Constructing Fins for Low-Power Rockets

By Tim Van Milligan

{Editorial note: This article was taken from the book: "Model Rocket Design and Construction." This book is will give you all sorts of ideas and techniques for designing and building your own rocketry creations. You'll find it at: https://www.apogeerockets.com/Rocket_Books_Videos/Books/Model_Rocket_Design_And_Construction}

Fins should be constructed so that they can withstand the forces expected during flight. The materials and methods of construction determine how much force they can withstand. Small models do not need very strong fins, and simple cardboard or balsa fins will suffice. Large models and those intended to fly at extremely high velocities will need more strength. The following list gives several materials and construction methods, in order of increasing strength:

- Thick cardboard (not corrugated)
- Balsa wood fins
- Plastic fins
- Balsa wood with paper reinforcing
- Balsa with spruce wood reinforcing
- Built-up fins
- Foam core fins
- Fiberglass reinforced fins
- Plywood

Cardboard is suitable for small rockets using up to a full A rocket motor. Straight balsa wood can be used for rockets of 0.91 m (3 feet) or less in height, using a maximum of a D engine. Larger rockets or higher-power models should use one of the other techniques or materials. Most of these methods will be described below. Since balsa is a predominant material, the chart describes the uses for the various thicknesses of balsa available.

Chart: Uses for Different Thicknesses of Balsa

0.79 mm (1/32")	Hollow built-up fins
1.59 mm (1/16")	Typical small rockets
2.38 mm (3/32")	Medium-size rockets
3.18 mm (1/8")	Larger low-power rockets or clusters; "C" or larger engines
4.76 mm (3/16")	Large cluster engine or heavy models
6.35 mm (1/4")	Generally too thick; high drag

If you plan to construct your fins from a solid-sheet material such as cardboard, plastic sheet, or balsa wood, first make a template of the fin shape so it can be transferred to the material. Before marking around the outside of the template with a pencil, orient the balsa sheet so the grain direction in the wood is parallel to the leading edge of the template. This will ensure maximum strength of the fin. If the fin grain is oriented parallel to the body tube, they will be very weak and will snap easily (**Figure 1**). These fins can be fixed by laminating both sides with bond paper as shown in **Figure 2 (Page 3)**.

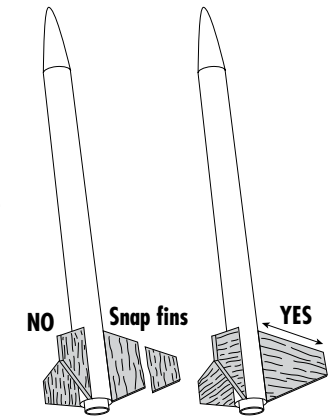

Figure 1: Orient the grain on the balsa wood with the leading edge of the fin.

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Designing and Constructing Fins

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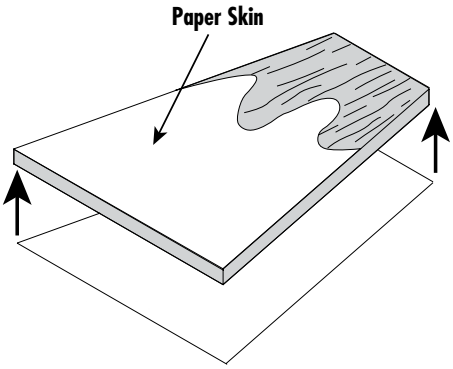

Figure 2: Adding paper skins to fins is easy and adds a lot of strength.

Sometimes it is necessary to make fins out of multiple pieces of wood. Such might be the case if the fin would be wider than a sheet of balsa wood (**Figure 3**), or if there is an undercut in the fin that would result in a fin that is structurally weak because of the wood grain direction (**Figure 4**). In either case, cut the wood so that the grain direction is oriented to create a fin with maximum strength.

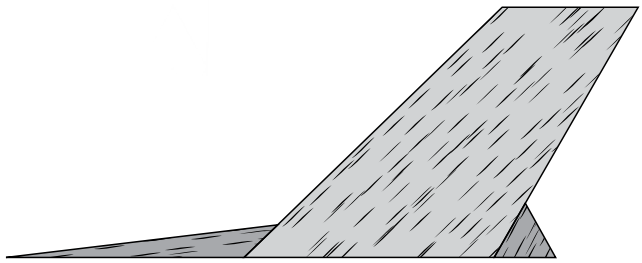

Figure 3: If the fin is wider than the width of the balsa wood sheet, you'll have to build it from several pieces.

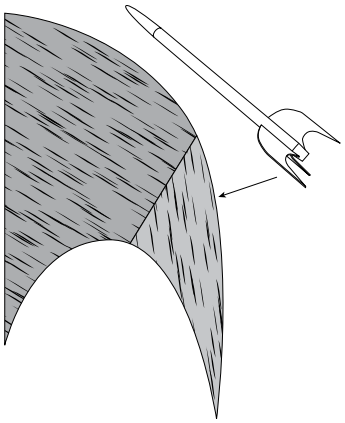

Figure 4: Multiple pieces of wood glued together (called compound fins) should be made for fins that have an undercut to them. Note the wood grain direction.

Fins with straight edges are the easiest to cut because you can use a ruler to help guide the knife. Lay the ruler on top of the fin to protect it if the knife blade should stray away from the ruler when you are cutting. Keep the blade at a 90-degree angle to the wood to avoid beveling the edges of the fin (**Figure 5**). When making cuts, make several light passes instead of one heavy cut.

Curved fin shapes are only slightly more difficult to cut. To ensure maximum uniformity between fins, make a template out of thick styrene sheet and use it to guide your knife blade.

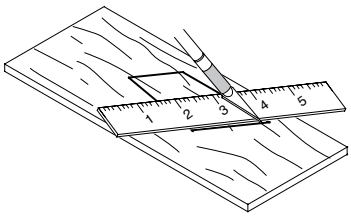

Figure 5: Place ruler on top of fin to prevent it from being sliced if the blade should stray from the ruler's edge

Thicker or harder materials such as plywood are more easily cut with a razor saw than with a knife (**Figure 6 Page 4**). Use care with a razor saw, since it is much harder to guide the blade and keep the edges straight.

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Designing and Constructing Fins

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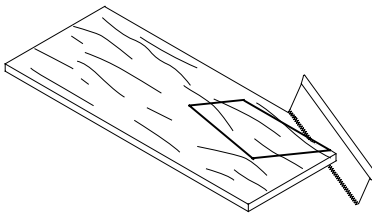

Figure 6: Use a razor saw to cut thick balsa and plywood.

After you've cut all the fins, stack them and sand them all together to ensure uniformity of size and shape. Pay particular attention to the edge that will be glued against the body tube (the root edge). It should be perfectly straight to maximize the bond strength of the fin. Also at this time, sand the airfoil into the fin. You might just round the edges, but for minimum drag the fins should be streamlined. Using a small wood planer will drastically cut your sanding time on thick fins.

If you want to have a definite high point on the fin, as would be needed on a scale model, lay a piece of masking tape along the dividing point (**Figure 7**). If you sand into the tape, remove it and lay a new piece down. This will give a sharp line on the fin.

Finally, give the fin an all around surface sanding. Remove any lines you drew with ink pens, as they sometimes bleed through the paint on the rocket and ruin its appearance.

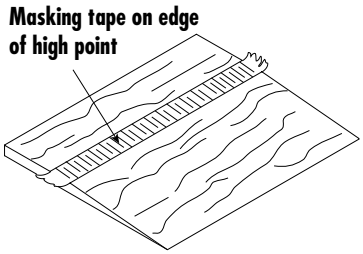

Figure 7: To make a sharp edge on a fin, use a strip of masking tape as a guide.

You may apply sealer to the fins at this time, too. You'll find it easier to sand the fins before they are attached to the body tube.

Reinforced Balsa Fins: Balsa fins can be strengthened by providing reinforcement. The additional strength will increase their stiffness and make them more resilient to stress incurred during hard landings. To do this you may either apply skins or add stiffer structural members to the fins.

Skins are the easiest to apply; you usually bond them directly to the fins with wood glue, instant glue, or epoxy. You can make them from a variety of materials, including tissue paper, ordinary notebook paper, cardboard, plastic sheet, very thin plywood, and fiberglass.

Stiff skins are usually applied to flat surfaces, as they are difficult to apply to fins that have airfoils sanded into them. To prevent a balsa wood fin from warping while the glue is drying, place it between two sheets of wax paper and lay a book or other weight on top of it. The waxed paper will protect the table and the book from glue that might ooze out.

Flexible skins that drape, such as tissue paper or fiberglass cloth, are better for curved airfoil sections. Apply tissue paper to fins or wings that need only a little reinforcing or to cover the grain of the wood, and use fiberglass cloth for applying maximum strength to any fin or

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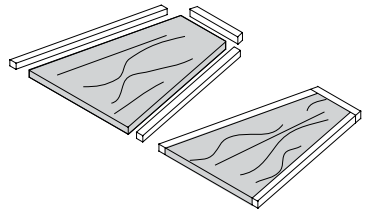

Figure 8: Hardwood cap strips add strength and keep fin edges from being dinged.

wing. The methods of application are similar, but the adhesives differ. Tissue paper is commonly applied with model-aircraft dope or wood glue thinned with water. Fiberglass is almost exclusively applied with epoxy, polyester resin, or instant glues.

You can also reinforce balsa fins by strategically adding stronger members to stiffen them. Members placed around the perimeter of the fin are called caps, while members placed inside the perimeter are called spars or ribs, depending on their orientation. Ribs lie parallel to the centerline of the rocket, while spars extend nearly perpendicular from the centerline (**Figures 8,9,10**).

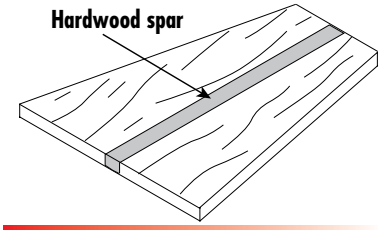

Figure 9: A simple hardwood spar helps prevent fins from snapping in two.

Built-Up Fins: A strong and lightweight fin, generally made hollow, with judicious placement of high-strength structural members inside an outer skin, is called a built-up fin. The advantages (if it is built properly) are low weight and high strength. Built-up structures are mainly used on large wings or fins, where weight reduction can be substantial.

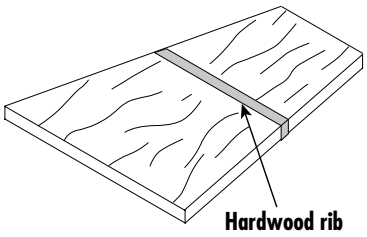

Figure 10: Hardwood ribs prevents fins from splitting along the grain of the balsa wood.

Figure 11 shows the key parts of a built-up structure. The spars carry bending loads, the ribs give support and contour shape to the skins, and the skin gives the wing an outer cover. When the skin is used to give strength to the structure, the wing is said to have a semi-monocoque construction. Skins that can be used effectively this way include balsa sheet, thin plywood sheet, and fiberglass sheet.

This construction is also suitable for fins with sharp leading or trailing edges. The skins on these have to be very thin and stiff; light cardboard, thin fiberglass sheet, or thin plywood - 0.39 mm (1/64”) or 0.79 mm (1/32”) work well. **Figure 12** and **Figure 13** (**Page 6**) illustrate how they could be constructed.

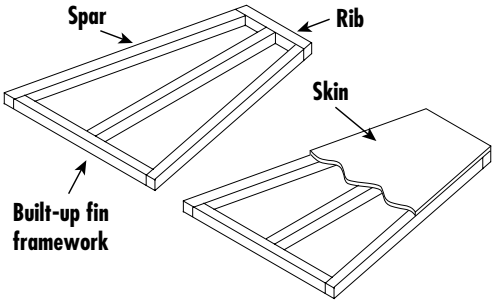

Figure 11: A simple built-up fin using hardwood strips and a skin of light cardboard or balsa.

Foam Core Fins: To increase the strength of a built-up wing, without significantly increasing its mass, you can insert expanded polystyrene into the hollow areas. This will add strength and stiff-

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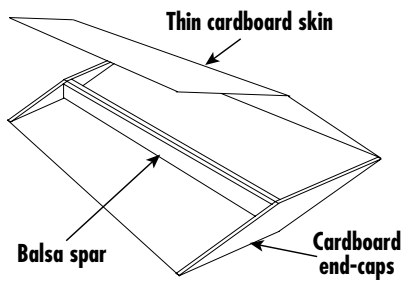

Figure 12: Wedge-shaped fins are easily made using a built-up method.

en the skins. The added strength is usually remarkable, so that many structural members inside the skin can be eliminated, and this decreases the mass of the wing.

Constructing a foam core structure is similar to building a built-up structure. Create a skeleton framework around the fin and cut a piece of foam to fit any hollow area. Shape the foam using a sanding block, so it exactly matches the perimeter defined by the skeletal framework. Bond the skin directly to the foam and all structural members. Epoxy is usually a safe adhesive to use on foam, but polyester resins and instant glues may melt it.

Again, the type of skin should be appropriate for the expected loads and the shape of the fin. Flat and stiff skins such as light cardboard, thin balsa, thin plastic, or thin plywood are suitable only to fins with flat surfaces. For curved surfaces, fiberglass cloth soaked in epoxy is generally better. Several layers of fiberglass can be added to give extra strength to the fin. This technique is especially applicable to larger and higher-powered rockets.

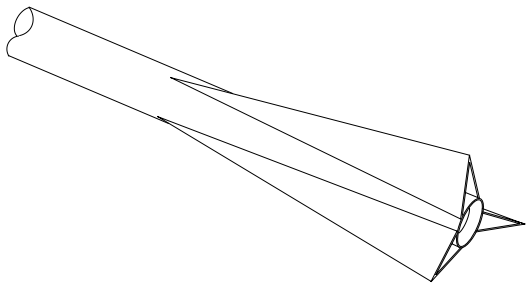

Figure 13: Folded cardboard fins without spars.

Plywood Fins: Plywood is not usually used as a fin material on small rockets, because it is difficult to cut and shape, and its density is too high for the strength it gives. However, it is used extensively in high-powered rockets. For small fins that need accurately shaped airfoils, however, plywood does have some nice characteristics. Use only 0.39 mm (1/64”) or 0.79 mm (1/32”) thick wood. For fins thicker

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Designing and Constructing Fins

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than this on small rockets, balsa is highly superior because the weight is significantly reduced compared to plywood.

Plywood is also acceptable for use as a skin on a built-up or foam core fin. When used this way, only thicknesses of 0.39 mm (1/64") or 0.79 mm (1/32") are acceptable. Thicker than this, and it adds too much weight without any significant increase in strength.

Many rocketeers think they need thick, solid plywood fins on larger model rockets and on higher-powered rockets. This is not always true. You can make strong and stiff fins with many of the methods described above. Just take your time making the fins and do the job right. Many modelers can attest that they have built high power rockets using balsa fins that have been reinforced with spars and/or fiberglass skins.

About The Author:

Tim Van Milligan (a.k.a. "Mr. Rocket") is a real rocket scientist who likes helping out other rocketeers. He is an avid rocketry competitor, and is Level 3 high power certified. He is often asked what is the biggest rocket he's ever launched. His answer is that before he started writing articles and books about rocketry, he worked on the Delta II rocket that launched satellites into orbit. He has a B.S. in Aeronautical Engineering from Embry-Riddle Aeronautical University in Daytona Beach, Florida, and has worked toward a M.S. in Space Technology from the Florida Institute of Technology in Melbourne, Florida. Currently, he is the owner of Apogee Components (http://www.apogeerockets.com) and also the author of the books: "Model Rocket Design and Construction," "69 Simple Science Fair Projects with Model Rockets: Aeronautics" and publisher of the "Peak-of-Flight" newsletter, a FREE e-zine newsletter about model rockets. You can email him by using the contact form at: https://www.apogeerockets.com/Contact.