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APOGEE

PEAK OF FLIGHT

NEWSLETTER

Model Rocket Origami

Using Paper in Unusual Ways to Make Unusual Rockets

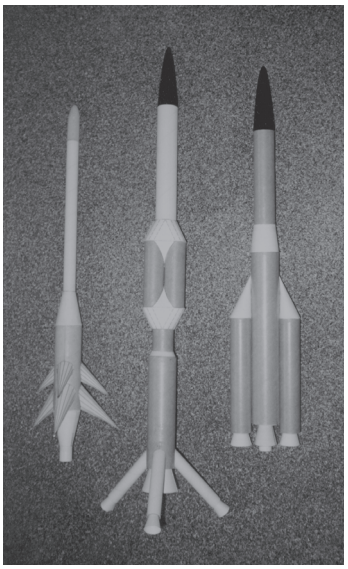
By Tim Van Milligan

Paper is truly a wonderful building material for model rockets. Did you ever really sit down and think about its characteristics? It is light weight, strong, accepts almost any type of glue, can be easily painted, and is both bio-degradable and recyclable. When used in the construction of a rocket, it is one of the safest materials to use, because if it hits something, it crumples in on itself without shattering. This is the best way to rid the kinetic energy of rocket with the least amount of damage.

The variety of paper types is immense; as defined by its construction and material components. For example, think of all the different types of paper products: tissue paper, wax paper, newsprint, crepe paper, cotton rag paper, bond paper, light cardstock, heavy cardstock, corrugated cardboard, Bristol Board, and molded paper products; to name just a few. And papers comes in even larger assortments of weights, colors, textures, and finish coatings. For component materials, paper can be made from a wide variety of organic materials: wood pulp, cotton fibers, and the latest craze; hemp fibers.

The natural fiber paper products retain many of the wood-like qualities. They can be cut, glued, sanded, painted, and shaped with the same type of wood working tools. Another "wood-like" quality is that most papers have a grain direction. To see this for yourself, take a piece of newspaper and tear it. You'll see that if you tear it one way, you get a fairly straight line, but the other direction, it is very jagged. This makes it stronger in one direction than the other; and you can use this to your advantage. You can also see that the grain direction will make a difference in the sharpness of a fold. If you fold perpendicular to the grain direction, the crease isn't as sharp, and may try to straighten itself out.

And if the natural fiber-based paper products are not enough, there is even synthetic varieties that have other characteristics. Think of Tyvek (a polyester based paper) which doesn't tear at all, spun woven nylon (like a Bounce fabric sheet) which makes a great hinge material because the fibers stay springy, and even Nomex paper that that doesn't burn. Paper is also used in combinations with other materials too: I can think of "Foam Core" products which are really strong and can be used to make fins and even glider wings.



But this article is about the wood based products, because they can be more easily used by average modelers. The characteristic that I like about paper is that you can shape it in a variety of ways. The best and most obvious example for rocketry is that it is easily rolled into body tubes. You can also "roll" it to make conical nose cones and transition sections.

There is one type of paper is better suited to rolled cones and transitions. It is called Bristol Board. You can find Bristol Board in varying thicknesses at the better artist supply stores. What makes it unique is that it is made up of two or more layers of paper where the grain of individual layers is placed perpendicular to each other (like plywood). What this does is to make it strong in nearly all directions, and it doesn't crease as easily. So for rolled conic sections, like nose cones and transitions, it yields a "better looking" part which is actually stronger for the same weight as other types of papers.

Flat sheets, or panels of paper, can also be used as fins on the rocket. The easiest way to do this is to use thick cardstock.

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A lot of small rockets (1/4A through B) use paper fins in this manner. A nice feature of paper fins is that they do not chip apart from hard landings. If a paper fin is bent, it can easily be repaired by wicking water-thin CyA glue on the crease to increase its stiffness and strength. But since the grain of paper isn't as strong as the grain of wood for the same weight, for larger rockets, you typically use wood fins.

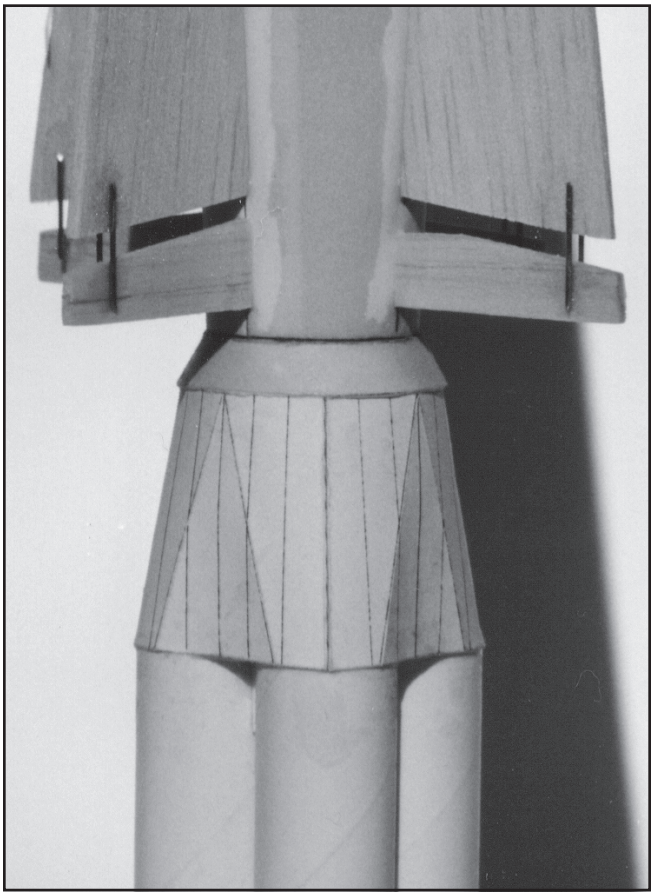
But to make these wood fins even stronger, you can add a layer of paper to both sides! Tissue paper applied with aircraft dope works well and adds very little weight. And at the same time, it makes the surface smooth and can be used to colorize the rocket. For a stronger fin, I like to use ordinary bond paper applied with wood glue. You need to coat both the wood and the paper with glue to assure that no air bubbles get trapped under the paper; and you need to do both sides at the same time to lessen the warpage of the wood.

But fairly strong paper fins can be made using the built-up method too. This is where two skins of paper are separated by structural spar. This method is particularly useful in making "scale" fins - like on a "Nike" rocket. The fact that you can get a sharp crease on the high point and both the leading and trailing edges makes it easier to construct than sanding a solid balsa wood fin. And sometimes, you don't even need a structural spar inside the built-up fin to give it strength. I submitted an "all paper" fin model rocket design to many newsletters around the country. You may have seen it and even built one yourself.

Creating a cone or a transition section from paper is pretty easy. The simple equations to begin the construction process are found in either the book *"Model Rocket Design and Construction,"* or *"The Handbook of Model Rocketry."* Or if you prefer, many of the rocketry software programs now have a feature to generate patterns from dimensions you input. Once the pattern is transfered to Bristol Board, you can begin to cut it out using a hobby knife.

Curling the piece would be the next step in the assembly sequence. You can do it over the edge of a table; although this must be done carefully to get the curl in the correct direction. The method is similar to making curly ribbons for wrapping presents; pull down hard, and fast. The fibers will stretch slightly giving the desired curl.

But I prefer to carefully wrap it around the handle of a hobby knife. It is more forgiving of errors. For tight curls, like on the point of a cone, I use a 1/8 inch diameter wood dowel as a curling tool.



Paper Pattern development can be used to create complex shapes, like this transition on a Nike Hercules rocket.

If you are making a pointy cone, it might be better to make two separate cones, one out of light -weight bond a paper, which is easier to curl, and will yield a sharper point; the second you could construct out of a heavier weight index cardstock. This second cone is glued inside the lightweight cone to give strength to the piece.

Gluing the edges of the cone or shroud together should always be done with wood or white glue. It allows you to reposition the edges to get the correct fit before the glue dries.

About this Newsletter

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It is also flexible, and can be curled itself; unlike CyA glue which is brittle. Depending on the type of paper used, I sometimes like to come back and saturate the paper fibers with water-thin CyA glue. This adds incredible strength and seals the fibers so they can be sanded down very smooth. Coated papers, such as those with a glossy finish, don't seal well with CyA, and therefore don't need to be sanded down later. Usually one side is un-coated and has a dull finish; this is the side you'd apply the CyA into to add strength. This dull side should also be oriented to the inside of the piece.

transition_assembly.mov

Instructions: Click on the box above to start the movie playing.

The overlap used to aid gluing, is often an eyesore, particularly on "scale" models. To get rid of the seam, you have two options. First, on large diameter cones, you can press down on the "inside" of the seam with a fingernail. This can stretch the fibers and crease the paper so that the overlap is less pronounced. After the cone is glued to the rocket, you will have to come back with some filler putty and fill any gaps. Sometimes this will deform the part, so that the cross section isn't perfectly round, but has a point - like a teardrop. You may need to reform it before gluing it to any tubes so it is perfectly circular.

On cones 18mm dia and smaller, that method doesn't work well, so you should leave off the extra glue tab when you cut out the pattern. Use a separate piece of paper, and glue it over the joint between the two inside edges being joined. This should leave a very thin join line on the outside of the part which can be filled later with putty. The drawback is that you don't have the ability to reposition the part while the glue dries, so your pattern has to be fairly exact when you cut it out. You can also use this method on large cones too.

Cones or truncated cones made using this method can be purely decorative too. I like to make "simulated" rocket nozzles that add a lot of pizzaz to most models.

"Molded paper products" is pretty much the only other way to make complex and compound curves out of paper. You've probably seen molded paper in the form of egg cartons at the supermarket. The are formed by making a thick water slurry of paper fibers and pouring it into a two part mold. The mold halves are brought together under a lot of pressure which squeezes the water out of the fibers. Typically, one side of the mold has a mesh surface which allows the water to escape. One side will be fairly smooth, and the other side (against the mesh) will have a rough texture. The part is then removed from the mold and allowed to dry. Big parts with thin wall thicknesses can be made this way. I've seen very large plant pots made out of this method.

I think we've all made molded paper products as juviniles in the form of spit wads! But for rocketry, molding paper hasn't really caught on due to the intensive set-up required to make molds. A simpler way may be to use a papier-mâché set- up. I think a neat use of molded paper would be to make a shroud for a McDonnell Douglas Delta Clipper type model that is a big flying shroud with a rounded nose. It could be made both light and strong with this method.

Flat sheets of paper can be folded into very complex shapes; which is where the title "Rocket Origami" comes from. Cutting, folding, and gluing paper is an art-form that I think can be taught to most modelers. But before this can happen, you have to have a desire or need for the shaped part. So what types of items can be made?

As mentioned before, the obvious ones are tubes, nose cones, transition sections, and simulated nozzles. If you look

in some old rocketry catalogs, you can find some others too: cockpits, and simulated jet engine inlet ducts. The variation of designs is only limited by the imagination of the builder.

Making 3-D parts this way using flat sheet stock is called "pattern development." The easiest pattern development to make is the cube. If you unfold a corrugated box, you'll see how this method works.

What makes pattern development challenging and fun is making two different 3-D objects mate to each other. This is where textbooks that teach engineering-type "drafting" come into play. If you are really interested in doing complex rocket origami, the books will show you "step-by-step" how this is done.

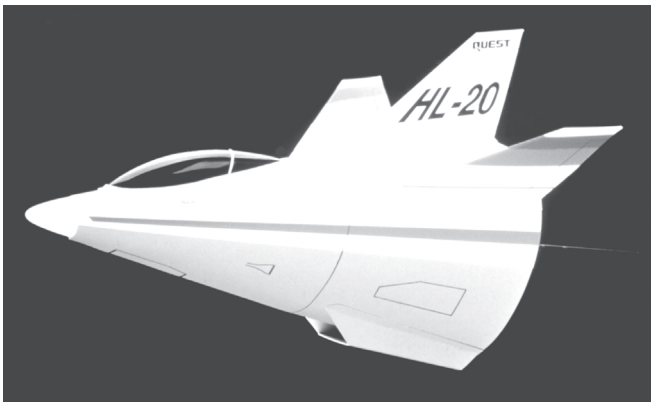
For a simple start, I'd suggest designing a paper cockpit. Basically you could start with a cube and see how to mate it to a tube. If you leave one end open, now your cockpit becomes a jet engine intake duct. Then you could start changing the cockpit or intake duct by making one side an angled piece (now the cube becomes a prism). By continuing to stretch the shape of the prism, you could turn the cockpit into a long shroud -- like the conformal tanks on a NASA X-15 rocket plane.

A variation of the conical transition piece would one that transitions from a circular tube to a rectangular or triangular tube. I first used this method on a rotaroc style helicopter; I needed a triangular tube to give me a flat area to mount the hinges for the blades.

You can add even more challenge to the pattern development process by mating two curved pieces together. I'd start by changing the simple right angle nose cone to a "oblique" cone; where the point is not over the center of the cone base, but off to one side. This could give you a nose cone for a Ariane or Proton scale model.

For modeler's who want to go to the extreme, how about trying to mate two tubes together at an odd angle? This could be used to duct the ejection charges of side pod motors into the core tube of a model. You could use the same piece to create another type of simulated jet intake duct, but with a circular opening. I've used this same method to make tube fins that jutted out into the airstream and that looked like thick dowels.

And other combinations are possible too. I've made "cone fins" and transitions that make it possible to mate together a cluster of two tubes down to one single tube. To date, the most complex part I've made is an oblique cone which mates with two tubes; that allows ejection charge gases to vent into the core tube from a pod tube. This is one method that could be used for the NAR 6-C cluster altitude competition model. A copy of that very complex pattern has been printed in many club newsletters.



The Quest HL-20 is a complex-shape paper rocket. The cockpit is molded from plastic.

For modeler's that would like to 'cheat' and see what other finished parts might look like, you can purchase Apogee's "Designer's Resource Pak" which includes all of these different pieces listed above. A nice feature of the parts is that with a photocopy machine, you can change their size so they even can be used on big model rockets!

Finally, you can even make entire rockets out of large shaped shrouds. The classic examples are some of the kits produced by Quest. The "Space Clipper" and their version of the NASP are excellent examples of the types of rockets that we can all create ourselves. The added advantage is that all types of surface decorations (panel lines, heat protection tiles, insignia, etc.) can be printed on the outside of the paper, so that the finished model looks really complex, even though it is simple.

Oh... I just remembered the most important characteristic of paper that makes it a great choice for rocket builders. It is cheap! Most times, it is even FREE! So if you are limited by your rocketry budget, it is the "best" material to use for construction. So get to know it; find out its advantages, its limitations, and ways to shape it. Then you'll develop a great appreciation of its many great qualities.

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Tim Van Milligan is the owner of Apogee Components (http://www.apogeerockets.com) and the curator of the rocketry education web site: http://www.apogeerockets.com/education. He is also the author of the books: "*Model Rocket Design and Construction*," "*69 Simple Science Fair Projects with Model Rockets: Aeronautics*" and publisher of the FREE e-zine newsletter about model rockets. You can subscribe to the e-zine at the Apogee Components web site, or sending an email to: ezine@apogeerockets.com with "SUBSCRIBE" as the subject line of the message.