Composite Fin Construction

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INTRODUCTION

The technique for constructing composite rocket fins was developed over a span of two years by the Texas A&M Sounding Rocketry Team. The goal of the technique is to construct rocket fins in a repeatable way that was accurate to the design in order to ensure smooth and predictable flight. Past methods used by the team yielded sub-par results; for example, finished sets of fins would not come out with consistent dimensions. The new method incorporates several steps, but is not an overly complex process. The process is broken down into four major steps: machining the aluminum fin base pieces, carving the foam fin cores, applying carbon fiber through a process called vacuum assisted resin transfer molding (VARTM), and finishing.

FIN BASE PIECES

The base pieces of the fins are solely for ease of attachment to the tail cone of the rocket. The root surface that will contact the tail cone has the curvature of the tail cone itself so that the fin rests flush against the tailcone. The base piece has the overall airfoil shape of the fin, and is simply meant to replace a small section of the fin at the root chord. The face of the base piece that will be inside the fin is flat, with several square holes for mouting stainless steel square nuts. The square nuts will ultimately be used to attach the fin to the tailcone; bolts are pushed through holes in the tail cone and screwed into the square nuts. Consequently there are smooth holes of greater diameter than the chosen bolts passing through the base piece, concentric with the square holes that house the square nuts. The fin base pieces are composed of aluminum for its strength and light weight, although most of the strength in the finished fin will come from the carbon fiber applied later in the process.

The fin bases for all of the fins are carved on a five-axis CNC mill; this ensures consistency (at this stage) between several base pieces and accuracy with respect to the shape.

FOAM CORES

High-density foam is ideal for this construction method, as it will not be crushed when subjected to the VARTM process described below. High-density foam is also more readily carvable on CNC machines; for this process, a CNC router was used to carve the foam cores of the fins. The cores themselves are slightly smaller than the desired dimensions of the end-product fin to accomadate the thickness of the carbon fiber sheet applied later in the process. The fin cores are also shorter than the desired span dimension of the fin to accomadate the aluminum fin base pieces such that the span of the fin base added to the span of the foam core results in the total span of the fin.

VARTM

VARTM maintains the effectiveness of a simple vacuum bag (with respect to producing strong and accurate composite parts) while allowing for a better epoxy-to-carbon fiber ratio, which for optimal composite strength is about 0.3 for this application. This VARTM process is two sided for the fins, and requires the following materials: elastic vacuum bag film, plastic resin infusion mesh, nylon release peel ply, gum tape, and carbon fiber. A vacuum pump, resin catch pot, a spiral tube (infusion spiral), tube clamps, and several feet of tubing are also required. The first layer of vacuum bag is taped to clean, flat surface and gum tape is carefully placed along the perimeter. Then infusion mesh, peel ply, and carbon fiber – each cut to the proper shape of but larger than the fin – are placed in the center. The fin is placed down in the center and the infusion spiral is placed along one edge of the vacuum bag so that it just touches the infusion mesh. The layers are then repeated in opposite order on top of the fin. Tubing is attached to the infusion spiral and to the opposite end of the bag, the bottom layer of bagging is detached from the flat surface and the bag is carefully sealed. The exit tube attaches to a catch pot with a pressure gauge, and the catch pot is in turn attached to the vacuum pump. The system is clamped off on both ends after a vacuum is drawn.

Once the vacuum successfully holds for at least twenty minutes, the free – but still clamped – end of the tube that feeds the infusion spiral is placed in a reservoir of low-viscosity two part epoxy. The clamp on that tube is then released, and epoxy slowly works its way through the entire bag aided by the infusion mesh. Once epoxy reaches the exit tube and is sufficiently spread throughout the bag, the feed tube is clamped off tightly again, and the fin is left to cure. Under ideal conditions the fin will completely cure in 24 hours.

After the fin is cured (the carbon fiber is *very* rigid) it is removed from the bag aided by the peel ply, the excess carbon fiber is trimmed off, and the fin is sanded to shape.

SURFACE FINISHING

The fin can either be coated in epoxy, or several light layers of clear coat spray paint. Epoxy is preferred because it gives a better finish – the well-known "polished carbon fiber" appearance – and provides a more durable surface layer. The fin is then snugly attached to the tail cone, and a fillet around the entire root edge of the fin is easily made with auto body filler and subsequently painted.

RESULTS, CONCLUSIONS, AND FOLLOW-ON WORK

The result of this construction process is a rocket fin strong enough to withstand several times the expected flight loads, but flexible enough (thanks to the foam core) to withstand flutter and associated bending without snapping apart. The fin is also lightweight; much lighter than solid aluminum or solid carbon fiber (which requires a larger amount of epoxy). Fins made with this process are also more dimensionally consistent and accurate to all of the dimensions needed for the design.

The fins made using this process have been flight – and landing – proven; having guided the rocket on a straight flight with a very low roll rate, and sustained only minor surface scratches on the finish coat of epoxy after being dragged through rocks and dirt for several hundred feet. It is expected that the fins currently attached to the rocket will withstand all flights for the life of the vehicle.