

How to Create a Wing on the 3-Axis CNC Machine

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This tutorial explains in step-by-step detail how to use the 3-axis CNC router machine to create a micro air vehicle wing out of a block of construction foam. This will help to ease the learning curve encountered by previous MAV groups when attempting to make wings to be used for a MAV.

.TAP Files

Once the .tap files have been copied from the SurfCAM computer to the floppy disk, they must be transferred to the appropriate place on the DOS based computer that runs the CNC machine. The .tap files must be placed in the C:\CNC folder in order to be accessed by the CNC program. To do this, make sure the C:\ prompt is showing on the screen. Now, open the CNC directory by typing the following lines into the command prompt:

```
C:\>cd CNC  
C:\CNC>copy a:\top.tap  
C:\CNC>copy a:\low.tap
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Most likely, files of the same name exist in this directory, so you must confirm to overwrite them when asked. A confirmation dialog will appear if the files were transferred correctly.

Introduction to the CNC Program

A DOS-based program that is easy to familiarize yourself with controls the CNC machine. To start the program, once again make sure you are in the C:\CNC directory and type RUN. This should load up the program. Once you are in the program, you will see a number of different windows. The window on the upper right displays the coordinates (all units are in inches) where the mill is located. These coordinates are absolute coordinates, which means that there is a specific location for each X, Y, and Z value. For example, suppose the mill were at X = 8. If you typed X = 10 into the command window at the top of the screen, the machine would move two inches to the right. If this were based on a relative coordinate system, the machine would have moved 10 inches to the right.

The axes of the machine are set up in a right-handed coordinate system. If the observer is facing the mill, the positive X axis points toward the right of the table, the positive Y axis points toward the far end of the table, and the positive Z axis points directly upward.

To move the machine manually, you must first select a "transit mode." This controls the rate at which the machine moves when you hold down a certain key. Δ

F4: Fast transit
F4 (Held down): Slow transit
F5: Jog .001 in.
F6: Jog .01 in.
F7: Jog .1 in.
F8: Jog 1 in.

Left/Right Arrows: Move X
Up/Down Arrows: Move Y
PgUp/PgDn: Move Z

Creation of Mounting Plane

The next step in this process is to mount the foam blocks on the table of the CNC machine. First, cut out a block of foam that is at least two inches longer than the span, and at least one inch wider than the greatest width of the wing. This allows room for error and a space for the alignment holes. (NOTE: If you plan on cutting the wing out of the pink insulation foam, make sure that the chord of the wing is *parallel* to the small writing on the foam itself. Apparently, the pink foam has a slight grain to it, and orienting it this way yields a stronger trailing edge.) Next, select a block of foam that will mount directly to the table to serve as the plane place the wing block on. DO NOT mount the wing block directly on the table, for you must drill the alignment holes through this block of foam into something below it, in order to properly align the block after it has been flipped following the cut of the top surface. Mount the large block of foam on the table using double-sided tape. Make sure the tape used is adhesive enough to hold the block firmly in place. Double-sided foam tape is known to suit this task very well.

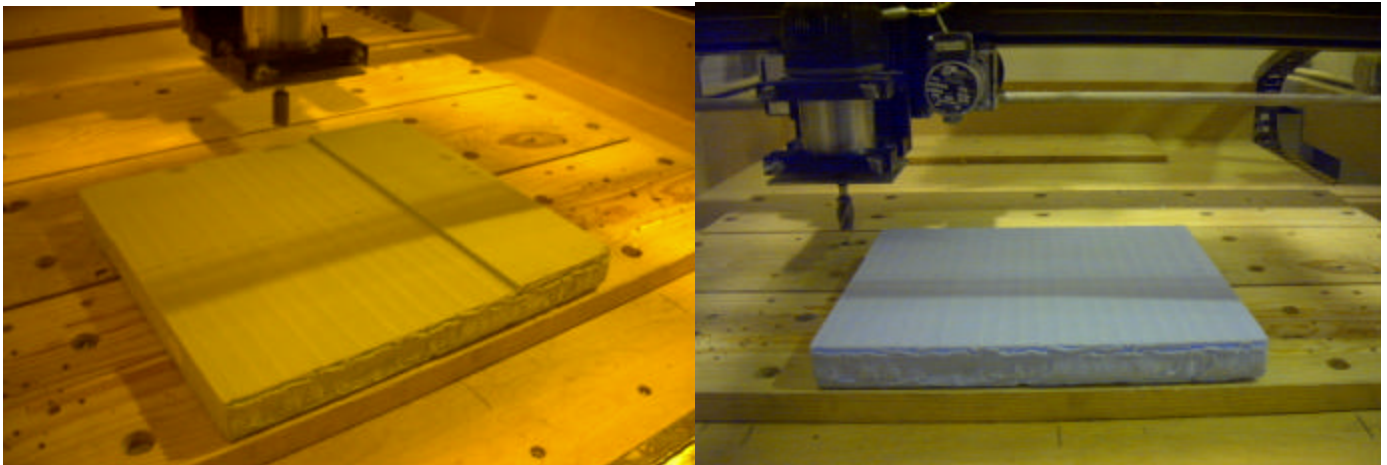
This mounting block serves a dual purpose. As stated earlier, it serves as a surface to drill alignment holes into. The other use of this block is to create a flat, planar surface (with respect to the end mill) to mount the wing block of foam onto. The table of the CNC machine cannot be trusted to be planar, because it has not been aligned with respect to the end mill of the machine. It is also a fairly thin board that may have warped slightly over the course of its use. Use of this as the planar surface may result in an unevenly cut wing, which will be most noticeable on the wing's trailing edge. To turn this block of foam into an adequate mounting surface, it must be planed by the CNC machine. This is accomplished using a flat-nosed end mill, such as the ones seen below:



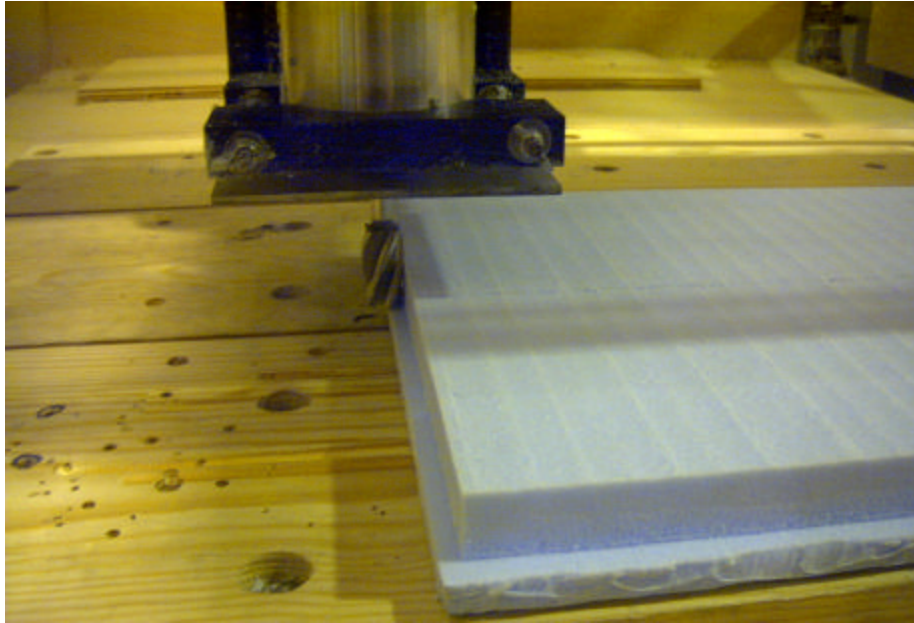
Flat-nosed end mills.

To mount the end mill into the router, locate the collett that corresponds to the diameter of the mounting shaft of the mill and the two steel wrenches used to torque the collett down. Insert the end mill with the collett in place into the router, and tighten to a tight fit. Be careful not to over tighten the collett as it may damage the router, or else become extremely hard to remove after the end mill heats up. Also, *make sure* that the collett being used is the proper size for the shaft of the end mill.

There are two ways to plane the surface of the foam. One is to create an appropriately-sized plane in SurfCAM and post it as a tap file. This .tap file can then be run to cut a plane. However, it is much easier to make the plane by hand, using the directional keys on the keyboard to control the end mill. Once the end mill is secured into place, determine an adequate depth to plane the surface such that the end mill will remove some foam in each pass. A depth of roughly .25 in. is usually plenty. Now, turn the router on, and maneuver the end mill across the foam, making sure to cover every point of the foam. This process is pictured below.



Simply run the spinning end mill along each edge of the plane to create a square perimeter of the plane, like the figure below:



A square perimeter around the planar surface

Setup of the Wing Block

Now that there is a straight edge to align the wing block with, mounting becomes simple. Since, in this case, the wing was created in SurfCAM with its span along the X-axis, the wing block must be mounted in this same direction. Make sure the longitudinal edge of the wing block is aligned with the near edge of the mounting plane.

The most effective tool to cut the wing out with is a ballnosed end mill, shown below:



the CNC program, the command G92 is used. Type G92 X0 Y0 into the COMMAND line to set the origin for the X and Y axes. Now, the Z axis origin must be set. This process is a little more involved. Technically, under different circumstances, a sheet of paper is placed between the end mill and the block, and the end mill is lowered toward the block at a small Jog rate. Move the piece of paper around, and continue to lower the end mill until it begins to provide some resistance to the movement of the paper. The thickness of paper is roughly .004 in., and this value must be added to the G92 parameter. For example, if the surface of the block were to serve as $Z = 0$, G92 Z.004 would be typed into the COMMAND line. However, under these circumstances, this step is not too critical for a number of reasons. First of all, the foam compresses as the end mill is pressed against it, which makes it nearly impossible to pinpoint the surface of the foam. Second of all, the foam wing must be sanded down after it is cut out, which makes a difference of .004 negligible. So, the best way to set the Z origin is to still use the paper method, which makes it easier to find the surface of the foam. Set this point as $Z = 1$ by typing G92 Z1(the origin is at the CENTER of the wing, and the foam block is two inches thick. Verify this).

Cutting

Now that the origin has been set, it is time to start the cutting process. For your first few times, you may want to relocate the origin and run the .tap file just to be sure that the mill will cut in the proper direction. Be sure to remember where your original origin was located. Cutting the wing out is the easy part. Simply turn the router on, and type TOP.TAP into the COMMAND line. The machine should start cutting out the top surface of the wing, like the figure below:



IMPORTANT: In the event that something goes wrong, there are two RED emergency

the operation. To resume, press a key on the keyboard. If the operation needs to be aborted, press the ESC key at any time during the operation.

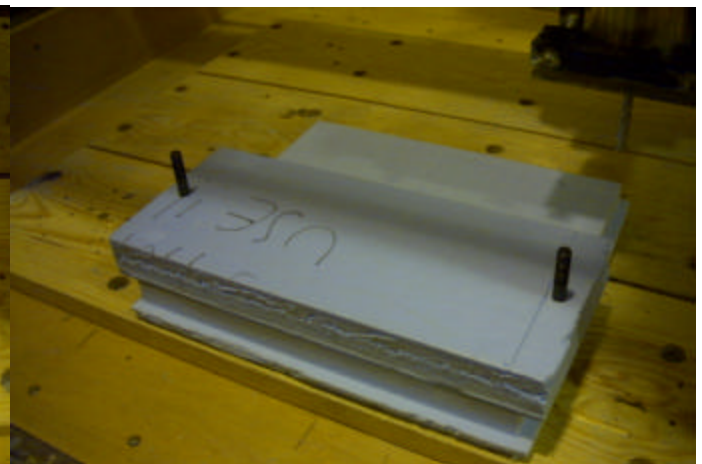
Flipping the Block

Once the top surface of the wing has been completed, the block needs to be flipped over. It is imperative that the wing maintains the exact same orientation on the coordinate system of the CNC table. The easiest way to ensure this is to drill alignment holes near the tips of the wing. Since the wing will be flipped SPANWISE (use the chord as the axis of rotation), the Y-position of the alignment holes must stay the same. The alignment holes must be drilled at the same distance from the center of the wing. To do this, type in an X value of about a half-inch or so past the tip of the wing. Make sure that whatever value you use for this is the same value, just opposite in sign. These holes can be drilled manually by using the PgUp/PgDn keys.

Once the holes are drilled, you may pull the wing block off the mounting plane. Find some rods that are the same diameter of the end mill you are using (usually 1/2 in.) to place in the holes once the block is flipped. See below:



Alignment holes



Use of rods to align the block

Now that the block is flipped, all there is left to do is cut out the bottom surface of the wing. The origin has remained the same throughout this flip process (hence the alignment), so there is no need to redefine it. Simple type in LOW.TAP, and the wing will be completed shortly.

TIPS

- There are many more G codes available to simplify the operation of the CNC machine. Consult the black vinyl folder located near the CNC machines in the ASL that contains the operation manuals for the 3-axis CNC router, the MAXNC

- After the wing has been sanded, run a dab of cyanoacrylate glue along the trailing edge to strengthen it.
- Glue balsa wood to the points on the wing that come into contact with the aircraft. This provides a much tighter fit, and also helps to strengthen the wing.