Uses and Capabilities of the Laguna IQ CNC Router

A thesis submitted in partial fulfillment of the requirements for the degree of Bachelor of Science degree in Physics from the College of William and Mary

by

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Abstract

The goal of this project was to investigate the capabilities of the Laguna IQ CNC Router in the William and Mary Physics Department's machine shop. This project originally started off with the goal of building and testing a CNC plasma cutter, but had to be switched due to health and safety concerns. During the time I worked on the CNC router project, I used Vcarve, a program to sketch vectors to cut with the router, to investigate the capabilities of the software to design 2D and 3D vectors, I used the CNC router to precisely cut the interlocking sides of a light-proof box that was used to aid in the research project being conducted by another student, and I created a brief write up on the basic use of the CNC router to be used in the future by students who are unfamiliar with the machine.

Project Overview

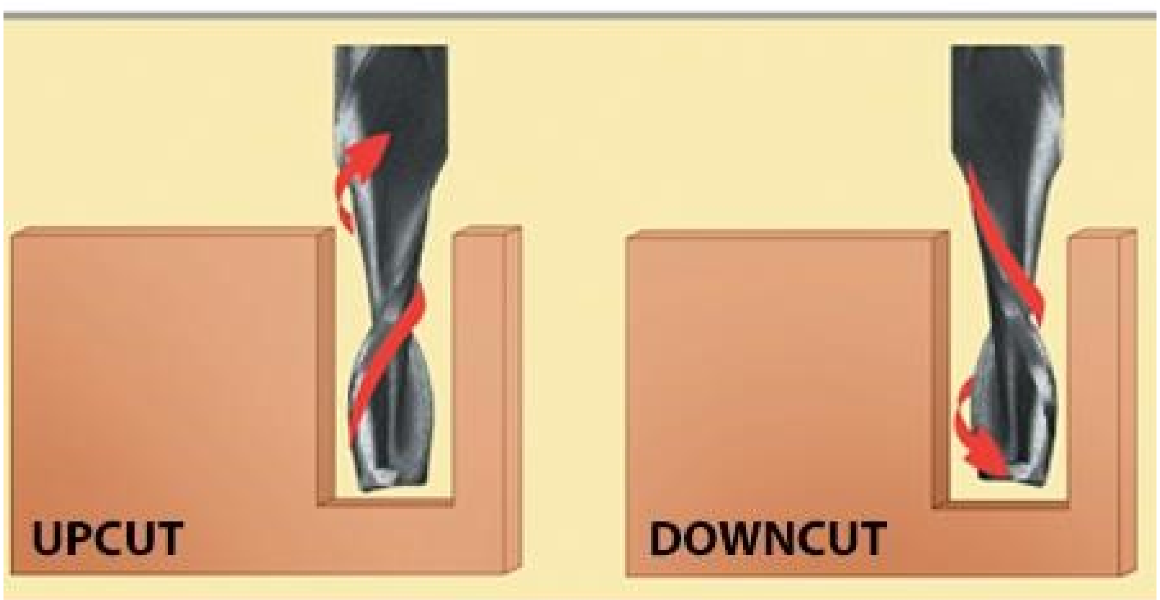
The CNC Router project tested what the new router in the W&M machine shop is capable of and the most straightforward way to use it so it can be effectively and safely used by students and faculty. To accomplish this, I used the Vcarve software to create various different designs that can be cut by the router, used the preview aspects of the software to view what the router was expected to do, and then cut several of the designs to subjectively see what the router was capable of. After becoming familiar with the router, I used it to precisely cut the sides of a light proof box that was used in another research project. These sides were made out of PVC board and needed to be cut to within a millimeter of the expected dimensions in order to properly fit together, making the CNC router the ideal tool to create these.

One of the original objectives of this using the CNC router was to test different materials, bits, and speeds to create a guide for future users on what speed and bit to use with different materials. However, by focusing on creating the box, that objective was changed and I instead used the process I went through to become familiarized with the router to create a small guide for other students to use in the future. This guide is intended to provide the basic knowledge needed to cut a simple design if a student needs to use the router to create a part for a project.

CNC Background

CNC, or computer numerical control, uses point-to-point commands to direct the control of a machine tool, usually consisting of two or three axes. To do this, positions, feed rates, and which tools are being used are inputted to whatever software is compatible with that specific CNC machine. That information is then converted into code, which can be specific to a machine or more generalized, like g-code, and that code is in turn inputted into the machine. A typical CNC machine will have a controller that includes an alphanumeric keyboard, functional keys, and a display. This allows for adjustments of the speed of the motors, spindle rate, positioning of the machine tool above the material being cut, and defining the origin in the X, Y, and Z-axes. Typically the Z-axis is where the tool the CNC machine uses is mounted. Given the variety of tools that can be used, different types of CNC machines include, but are not limited to, mills, lathes, plasma cutters, water jets, and, in this project, a router.

For this project, the CNC router used was the Laguna IQ. It has three axes, with a spindle mounted on the Z-axis for carving. It uses a handheld controller to make adjustments and is compatible with g-code as well as a specific coding option provided when using Vcarve. The Vcarve software allows users to import various files saved as bitmaps to then be traced as vectors to provide the X, Y, and Z positions for the router. Vcarve also allows users to specify what materials are being used, to include the size and thickness, and also what bit will be placed in the spindle so the software can produce an optimal route to cut. When the code is inputted to the router, it is capable of cutting at speeds between 6,000 and 24,000 rpm, depending on what material is being used and the complexity of the design. Since the router can work at high speeds, the spindle is water cooled so that on longer projects it does not overheat and become damaged or warp any of the router bits. The workspace available is 24 x 36 in with a gantry clearance of 6 in. This allows users to complete small projects on materials ranging from stiff foam to thin pieces of soft metal (although metal is not recommended since it can easily damage the machine and wear down the bits). The bits the machine is capable of using include straight router bits, up shear router bits, down shear router bits, and combination router bits. Straight router bits are standard bits that are commonly found in use with handheld routers.

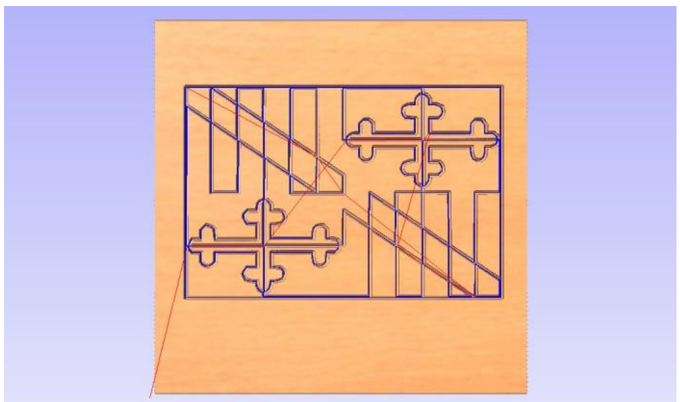


Examples of up shear and down shear routers bits
http://www.infinitytools.com/images/1088.jpg

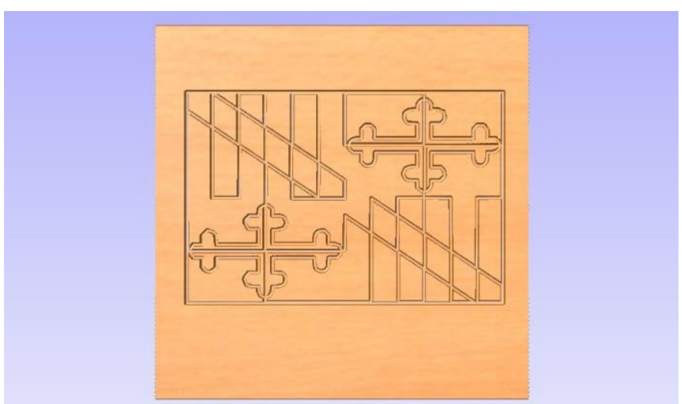
Up shear router bits are spiraled upwards in such a way that as it moves, bits of the material being cut are removed, but in doing so can also chip the top of the surface being cut. Ball nose router bits are a specialized variation of up shear bits with a more rounded end, which makes it especially useful when doing 3D cuts. Down shear bits are spiraled in the opposite direction of up shear bits, which prevents chipping, but causes bits or excesses material to be pressed back down into the material being cut. Finally, combination bits are part up shear and part down shear. The tip of the combination bit is up shear to prevent chipping the lower half of the material being cut and so excess material is removed, while the top part of the bit is down shear so that the surface of the material does not chip is the bit moves deeper into the material. Using these various components and the simple design aspects of Vcarve, the CNC router is able to do a variety of different projects of varying complexity.

Results

I started off small by using the clipart available in Vcarve to trace the vectors of a puzzle piece design that was available and then use the different spindle bit options in the software to model how the cuts would vary based on the different bits and depths designated. After completing the puzzle piece, I moved on to an image of a key I imported and then a picture of the Maryland flag (for fun and because it was more complex than the first two designs). The flag was more complicated in that to carve it required multiple profiles being used so the machine could properly outline the entire flag. An image of the vectors for the flag and the previewed flag are below. The final design was the William and Mary cypher, since it is extremely complex. Vcarve's trace function had no trouble tracing the vectors, but since some parts of the cypher are extremely small, not all aspects could be cut. To deal with this, I increased the size of the material being cut, changed the router bit being used, and varied between cutting to the outside of, inside of, and on the traced vectors. The best result came from using multiple profiles cutting to the outside of the vectors and using two different spindle bits to handle the extremely small and intricate cuts. Additionally, since the cypher has so many small pieces being cut, it would have required the tab feature of Vcarve, which keeps a small portion of pieces being cut out connected to the rest of the project so pieces are not shaking or out of place.



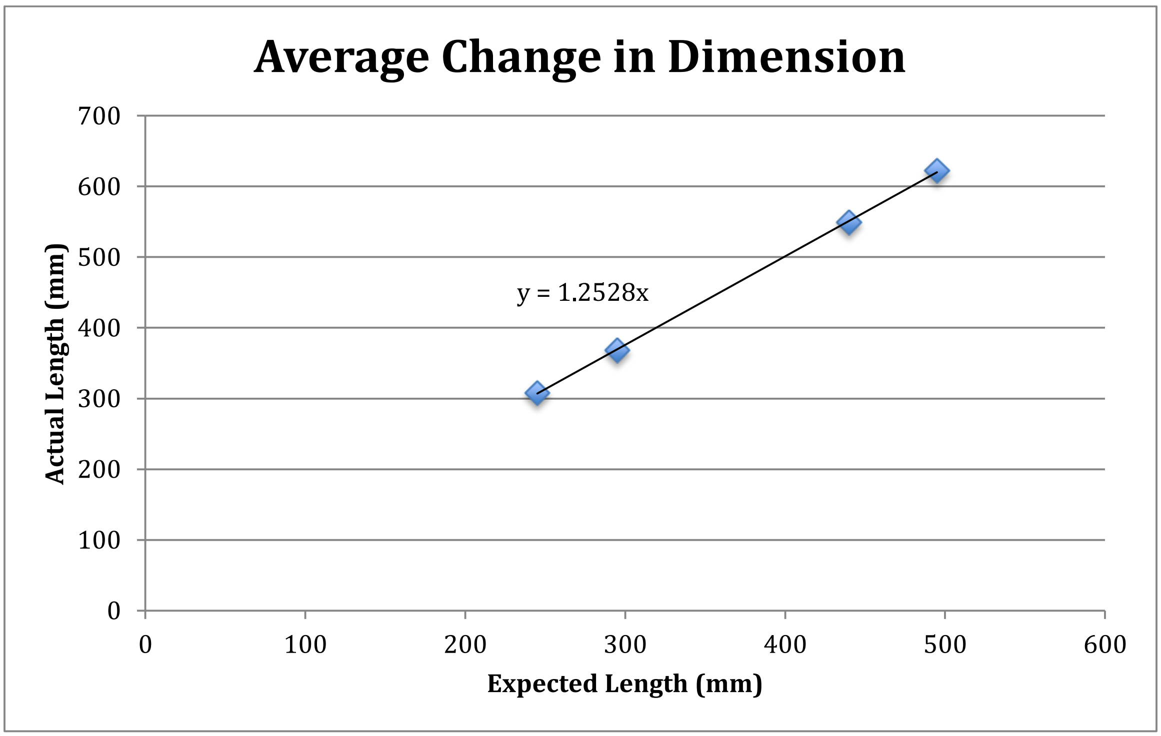
Above is an image from Vcarve of the Maryland Flag design with the tool paths showing where the router will cut the wood. Red marks where the router bit is raised and blue marks where it is cutting. Below is an image from Vcarve of the finished flag design.



After designing the more complex vectors, I moved on to familiarizing myself with the router itself. The router was fairly straightforward to turn on and set an origin in the X and Y-axes using the controller according to the user manual. The Z-axis was designed to be zeroed to the material being cut using an electronic sensor that came with the router, however the sensor did not work, so the Z-axis had to be zeroed manually. The easiest way to do this was to place a slip of regular printer paper on top of the material being cut and then lower the spindle, with the bit in, until it pressed the paper into the material just enough that the paper could not be pushed or pulled out from underneath the bit. This was actually an extremely precise way to zero the Z-axis and there was no deviation from the correct cut depth in any of the designs that were cut out.

When cutting, it was possible to select the work speed and spindle RPMs. Changing the work speed adjusted the speed of the stepper motors in moving the gantry and spindle. The spindle RPMs adjusted how fast the bit spun. For softer materials, it was possible to go at high or slow speeds for both, but with harder materials, like dense wood, it was necessary to have a slow work speed and medium to high RPMs for the spindle. Both of those could easily be adjusted with the handheld controller.

The last, and most significant discovery about the router is that it resizes the objects being cut. That is to say, if the vector designed in Vcarve was a 10 cm x 10 cm square, the dimensions would be changed between saving the tool path as code and when it was plugged into the router. This was discovered in process of making the sides for the light proof box, when the sides were designed in Vcarve to be the exact lengths of the frame slots, but ended up being too large. It is not clear which element (Vcarve, the code Laguna uses, or the router) is responsible for the change in dimension. Fortunately, the change in dimensions is constant in each direction and could be accounted for when designing vectors in Vcarve (once it became apparent that this was an issue). In the X-direction, the conversion factor is 1.257. When attempting to cut out the sides for the box, the first design had a width in the X-direction of 245mm but came out as 308mm. After attempting to adjust this width when it did not come out right, it was set to 295mm, but came out as 368.3mm. The Y-direction was similar and had a conversion factor of 1.248. Using the two same designs to evaluate the X-direction, the original had a length of 440mm and came out was 549mm. The second had a length of 495mm and ended up being 622.3mm. The overall change in size was by a factor of 1.258. The Z-direction had no issues and cut to the correct depth. When cutting all the way through something, it would lover the spindle several extra millimeters to ensure that the bit cleanly cut through the material.



Above is a plot of the average change in dimension for an object being cut on the CNC router. The slope of the trend line is the conversion factor for resizing an object being cut.

Cutting the sides for the light proof box proved significantly more challenging than expected. The most significant issue was the dimension changes, which were just subtle enough to not be noticeable until it was tested with the frame to confirm its size. It then took two more attempts at resizing and cutting the sides to have enough incorrect sized pieces to measure them and determine the constant factor the dimensions were increased by. The picture below is of the very first attempt to cut the 295mm x 495mm, which ended up being the incorrect size, but did show it was possible to precisely cut a box side with the corners cut out and the edges trimmed so it could slot into the T-slot frame.

The final sides, with the Vcarve designs properly scaled, turned out almost entirely as expected, with one exception. On the largest side, the long end was precisely the right length, but the short end was 3mm too long and had to be trimmed by hand. This is likely due to an error on my part, since I neglected to use tabs when cutting, but should have done so when trying to cut a board of that size. By not using tabs, the board could have shifted due to the vibrations, leading to that deviation

Future Research

For any student who may choose to continue next year where I leave off, it would be beneficial to do what I originally intended and compile precise information on using the different materials, speeds, and drill bits to be used as a reference. This could allow students and faculty members hoping to use the router for their own projects to skip having to figure out which materials, bits, and speeds are most compatible and immediately be able to begin their project.

Works Cited

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Before Using the CNC Router

Safety

1. Before starting the CNC router, ensure you are wearing proper protective glasses/goggles

2. When using the CNC router, make sure to wear proper hearing protection, due to the loud and high pitched volume of the router while in use

3. When using the router, make sure to place all clamps being used in a position where the router bit and gantry will not collide with them

Zeroing Axes

1. To zero the X and Y-axes, use the handheld controller as directed in the user manual

2. To zero the Z-axis, place a piece of regular printer paper on the cutting surface and lower the router bit until it touches the paper just firmly enough that it cannot be pushed or pulled out from underneath. Then hit the Z-axis zero button on the controller.

Resizing

1. Before using the router, check your dimensions in Vcarve. Have you accounted for the x1.252 increase in overall size?

Recommendations

1. Check your design in Vcarve multiple times before attempting to physically cut it. If you have not done so, go preview your design now to make sure it will cut properly.

2. Always use tabs for your project. The router vibrates enough that it can alter the tool path while cutting by several millimeters

3. For soft materials, it is ok to increase the work speed and RPMs for the spindle. For harder materials, it is ok to increase the RPMs, but do not increase the work speed from the default.

4. Stay near the hand controller while cutting. If the router does something unexpected while cutting, you can hit the pause button to prevent damage to the project and the router