Multiaxis Computer Numerical Control Internship Report

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Abstract

Learning how to program, set-up, and troubleshoot multi axis machine tools is the topic of this internship report paper. The trainee, myself, started with experience in the 2 and 3 axis world of Computer Numerical Control (also known as CNC) machining centers and moved to the new world of 5 axis Computer Numerical Control machining centers. Of particular interest of this paper are the changes in technology over the last decade as well as issues related to machine tool resellers, CAD/CAM resellers, programming and set up differences between the existing machine tools and the new machine tool, and the learning curve of the trainee. The final goal of the trainee internship is to safely set-up, program, and execute a program on a new Haas 5 axis Vertical Machining Center using all 5 axis motions simultaneously. As noted in a recent article in Modern Machine Shop "Blindly heading down a "comfortable" path is certainly easy, but it might not be the best path to follow. Change can often lead to a better outcome even though it might force us out of our comfort zone." (Chaneski, 2012)

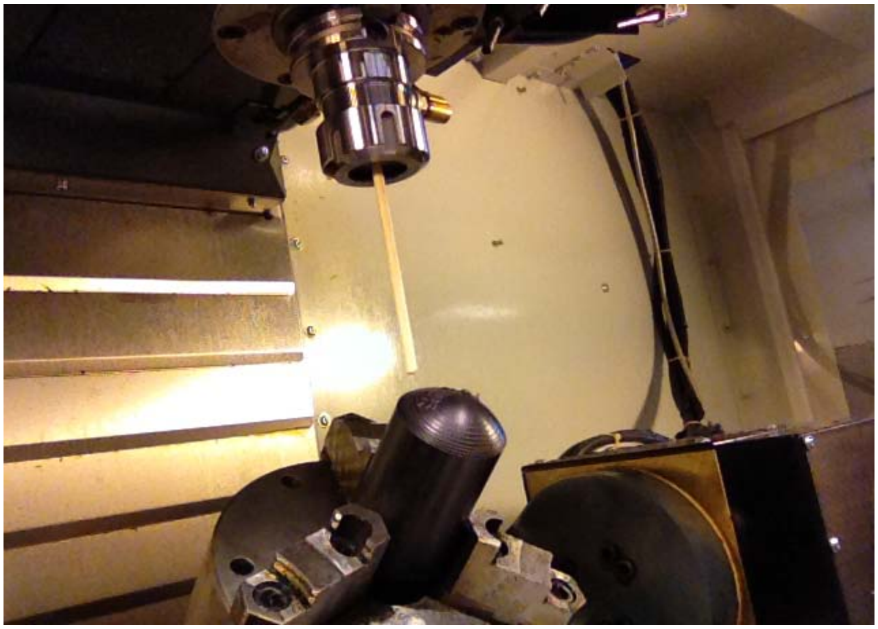
CHAPTER 1 Introduction

The goal of an internship is to gain knowledge and skill sets that are new and different for the individual but are also related to the field of study. The existing technology available in the machining lab at Mitchell Community College consisted of a various array of manual machines and two Haas CNC machine tools, namely a 2 axis turning center and a 3 axis vertical machining center. The two existing CNC machines had been acquired over 10 years prior to the purchase of the multi axis which was purchased in February of 2011 but not delivered until June of 2011. The older machines are used in basic freshman level CNC programming courses and the machining center also used in the freshman level introductory CAD/CAM course as well as a new course for sophomore level students, Advanced CNC Graphics, Mill, also known as MAC 232. Numerous local race teams, aerospace, and general machine shops are currently using multi axis machines for their day to day operations.

Job opportunities in these areas are available and consistently pay considerably more than other CNC programming/set-up positions. The Occupational Outlook Handbook 2012 does not delineate a machinist from a CNC setup/programmer or from a tool and die maker as far as salaries are concerned. Even more so, a multi-axis CNC programmer/setup machinist is not even searchable in the website. So using the median reportable income of $39,910 per year with a high school diploma and long term on the job training for a machinist is not exactly the picture the community college system is seeing. Local recruiters such as CAD/CAM Recruiters in Charlotte regularly advertise for mutliaxis CNC programmers/set up machinist at a pay range of $50,000 to $70,000. The industrial reseller for MasterCAM software in the Carolinas and Virginia has often inquired about potential employment opportunities for these skills. Clearly after 10 years with only a 2 and 3 axis machines available, it was time to move forward into more advanced levels of CNC machining. If new technology is not acquired on a regular basis, then you will fall behind and the students who attend these courses will also be behind the curve with their skills. “We cannot continue to operate in today’s economy and stay competitive without building a world class workforce.” (Eisen, Jun/July 2005)

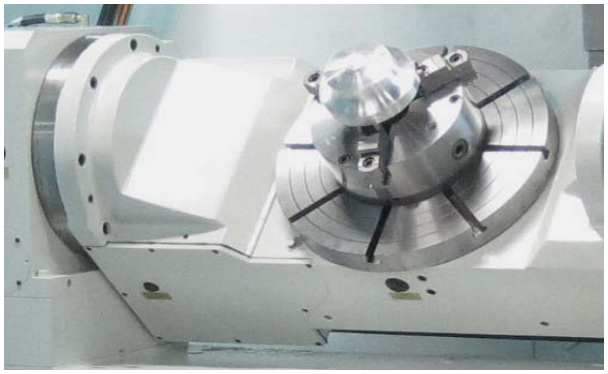
The next step will be the Swiss CNC machine tools that have up to 9 axis of motion. MasterCAM has recently launched a Swiss programming package to address this even more advanced level of machining to response to the increase in activity in this area. This activity is also seen in the local industries as well as in the advertisements for recruiters and the potential for income for people with skills in Swiss machining can break the 6 figure mark.

Current work published on multiaxis machining is not that common, however one particular book was recommended to me by a CAD/CAM industrial reseller for the Carolinas and Virginia, Jim Wakeford. The book, “Secrets of 5-Axis Machining” by Karlo Apro and published by Industrial Press in 2008 was a starting point for learning the basics of high level CNC machining. Karlo Apro is a well- known multi axis machinist. Mr. Apro has worked in manufacturing in his native Hungary and then Germany for over 30 years. The last 15 years he has focused on multiaxis machining and he also has experience with many different CAD/CAM systems. Mr. Apro dispels many myths associated with multiaxis machining such as it being too expensive and hard to use and that there is not enough work for multiaxis machining to justify purchasing and or learning how to use the technology. The method of learning how too safely set-up, program, and safely create a simple part using all axes simultaneously is outlined in the following pages of this report. One of the suggestions from this book is the use of wooden tools to check out tool motion. If there is a crash then you only have minimal damage. In the following picture you will see the wooden end mill in the tool holder and the spherical part in the chuck.



CHAPTER 2 Method

An area of interest in the Apro book pertained to part home. Since the trunnion sits upon the table of the machine and the part is fixture in some fashion to the trunnion, part home is not programmed as it is in a basic 3 axis vertical machining center. From the picture of a similar trunnion, 3 jaw chuck, and part fixture in the chuck, it is obvious that a simple X, Y, Z on a corner of a rectangular part bolted to a mill table is no longer applicable.

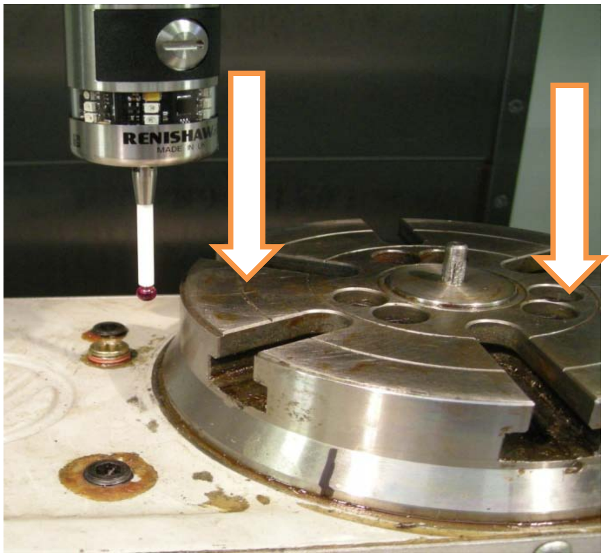


It was quickly apparent that the center of rotation of the axis brought upon by the trunnion played a key role in "teaching" the machine where the part was fixture in relation to the tip of the tool inside its work envelope. The machine cannot see or know how long a tool is and how close the tip of the tool is to the part or to the fixture. It has to be taught this during the set up phase as well as built into the software program when it is created.

Apro's book gives great detail on how to find the center of rotation which for a multi axis machine is the part home. He gives examples of machines with slightly different configurations such as table/table, head/table, and head/head. For this project, a table/table method is used. The sequence of setting the trunnion and creating an accurate part home which is the center of rotation starts off similar to a basic manual rotary table set up on a manual vertical milling machine.

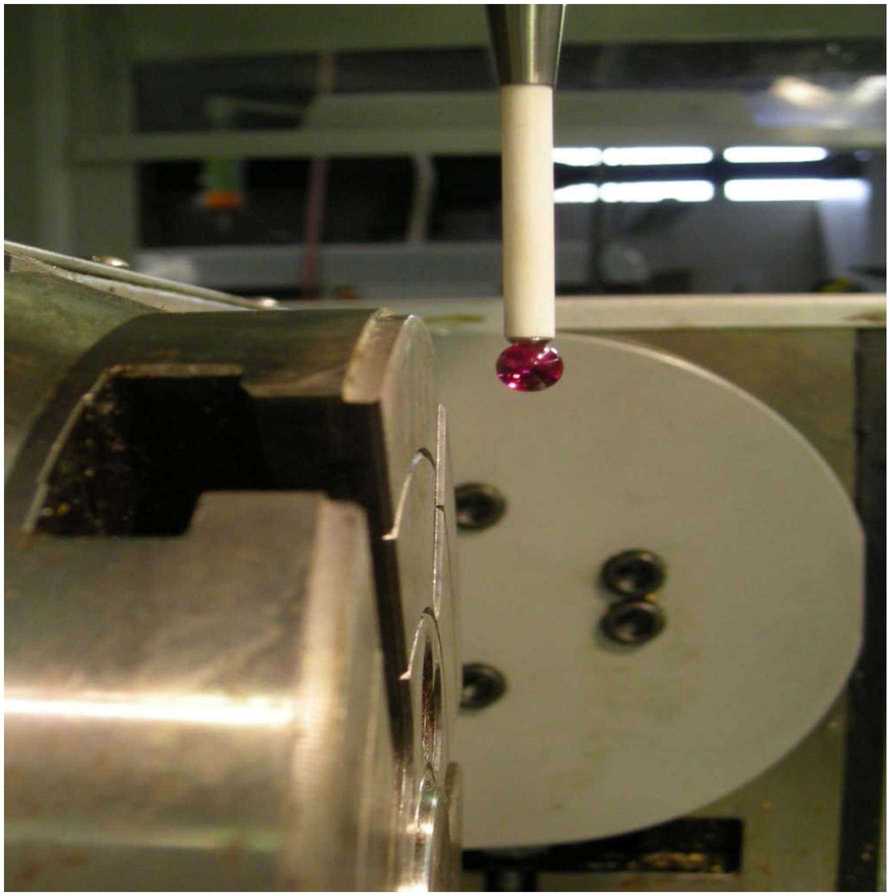
Step 1 You must indicate across the top of the trunnion platter and check to see if it is level. This is essentially checking to see if the Z axis is the same across the top of the platter. This can be done with either an off the shelf dial indicator or with a touch probe as shown in the picture below in Figure 1. If this is not level then check for burrs or trash under the trunnion that may be causing it to not be level or if this is not the case, use brass shims under the trunnion to bring it to level.

Figure 1 Checking level of platter with touch probe.



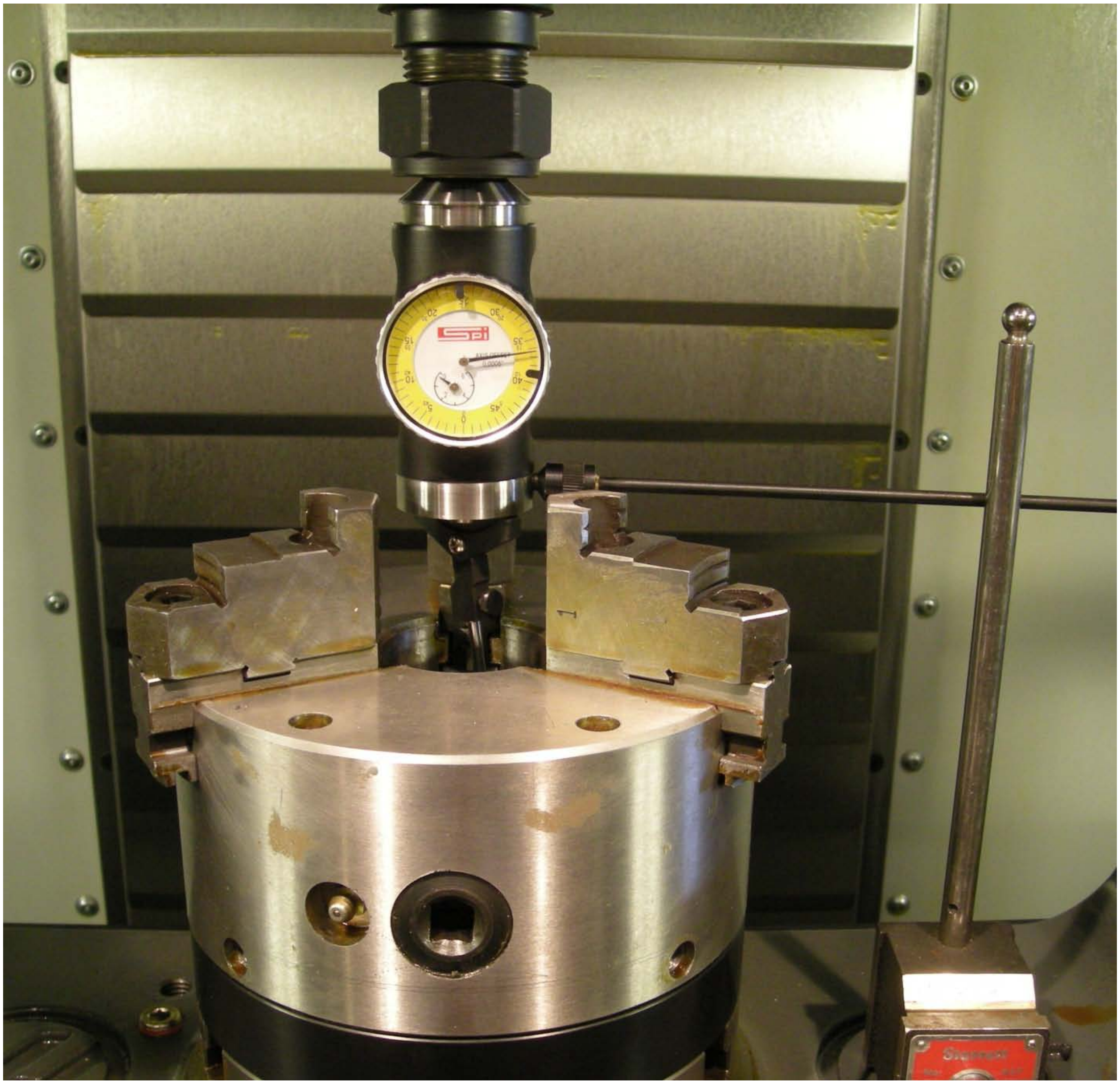
Step 2. Then you turn the platter to 90 degrees (A90.) using MDI or manual data input mode and check for alignment with the X axis of the table. Again this can be done with a dial indicator or with a touch probe. In Figure 2, the platter (and attached trunnion) is being aligned with the long X axis of the machine table. If sweeping across the trunnion shows that this is not aligned with the X axis of travel of the machine, then you have to physically jog the trunnion into alignment using a soft blow hammer.

Figure 2 Aligning the X axis



Step 3. Alignment of the center of the platter with the machine spindle is done with a coaxial dial indicator attached to the spindle. The last step in the basic set up is the center hole alignment with the spindle of the machine. This is the Y and Z axis alignment. Figure 3 shows the three jaw chuck attached to the platter and the hole in the chuck being used instead of the hole in the platter to align the spindle and Y and Z axis.

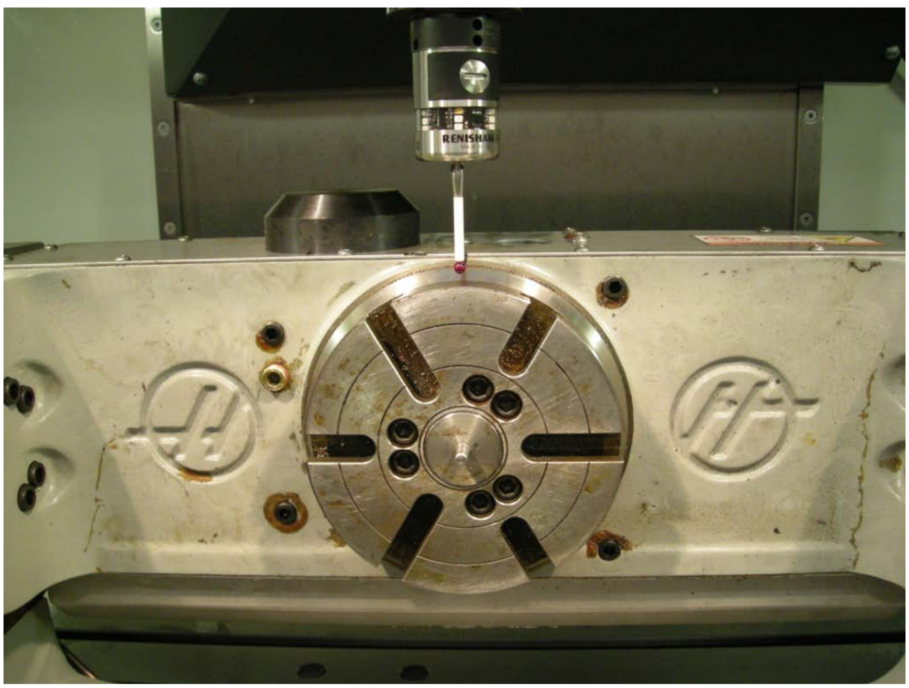
Figure 3 Co axial dial indicator



This concludes the first basic steps which again are similar to any rotary table set up for a manual vertical milling machine. The next step is to find the center of rotation for the A axis. This is the difference between basic 3 axis machining and 5 axis machining – the addition of the A axis.

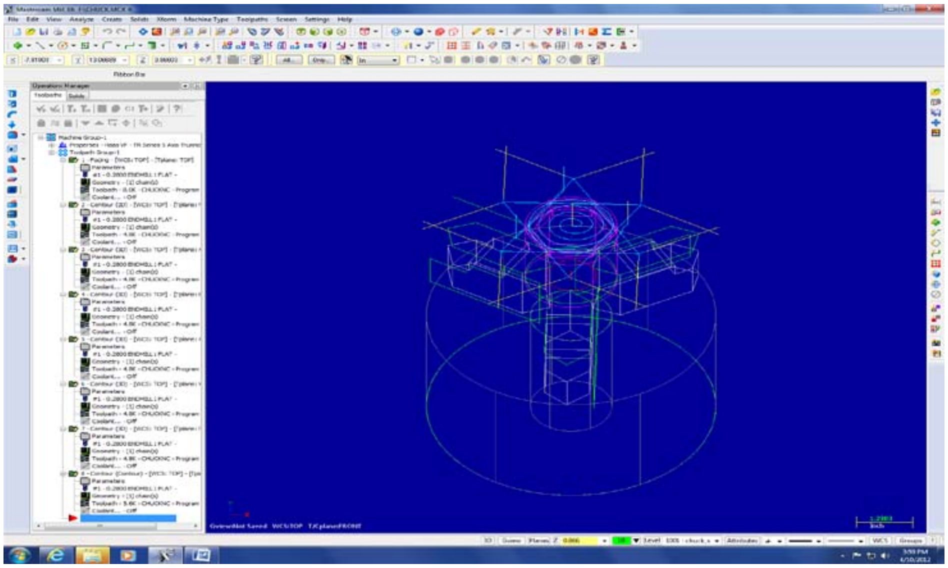
Step 4 Finding the center of rotation (or swing) of the A axis involves rotating the A axis to a positive 90 degrees and making note of the distance and then checking again at a negative A 90 degrees. Figure 4 shows the outside of the platter being checked for height. The distance of this position should be ½ the diameter of the platter. After rotating to A-90.0 and touching the outside of the platter should give the same distance. If this is not the case, then recheck previous steps to make sure they were done correctly, otherwise adjustments will have to be made to either the machine offsets or in the CAM system.

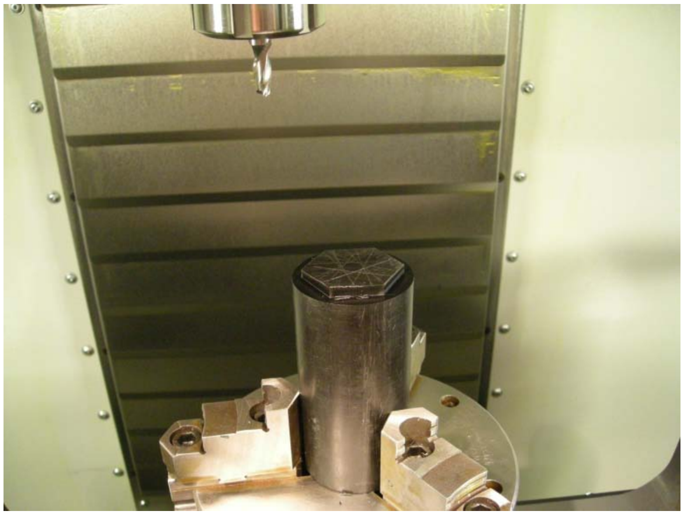
Figure 4 Checking edge of platter.



As the alignment of the trunnion is established, this will become your part home and is assigned G54 or a work coordinate that will not change as long as that particular fixture is being used. For the particular machine in this internship, the chuck was carefully measured and recreated in the software to be used as a visual reference for tool path creation. In the following figure, a simple part and tool path was created on top of a solid model 3 jaw chuck. The distance from the top of the chuck (which is used to touch off tools) is 3.895 inches. This number is used to "teach" the machine where the tip of the tool is in relation to the permanent G54 part home in the machine. In a sense, your part will "float" above the center of rotation of the trunnion and will not collide as long as you maintain the 3.895 distance with the tools.

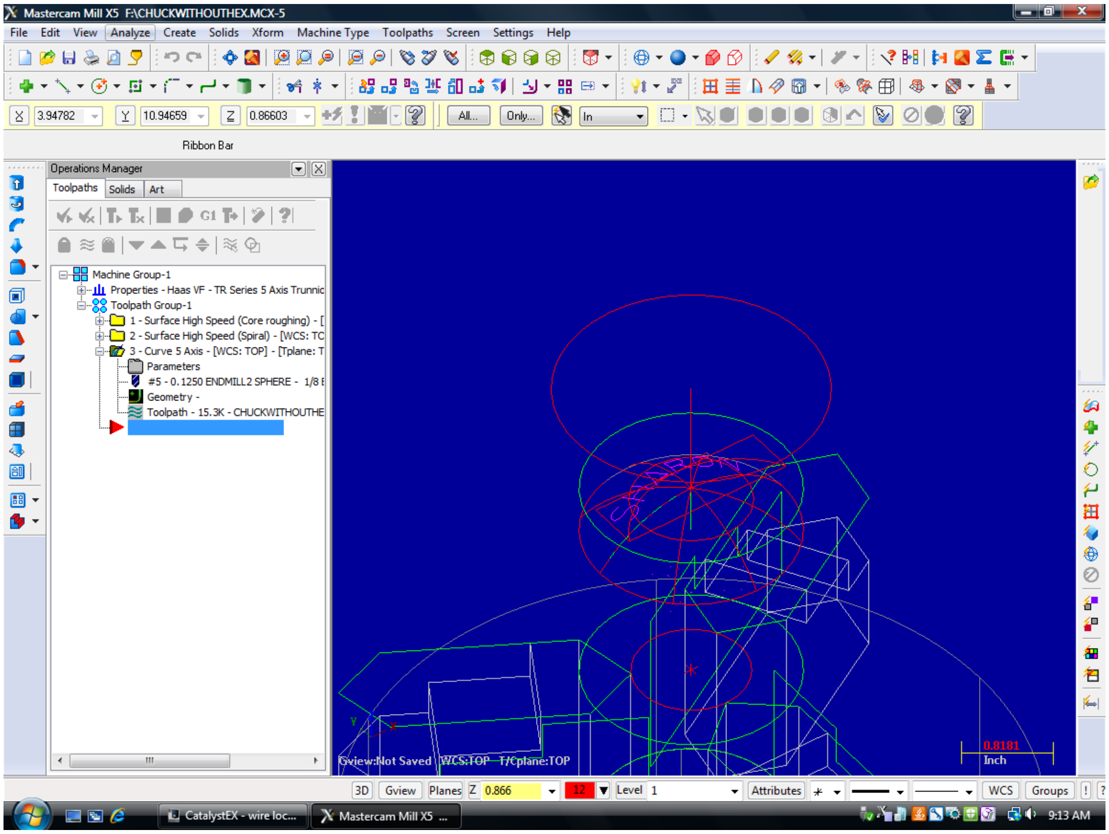
Figure 5 MasterCAM screen shot of basic hexagonal part and part made on machine.





This program was used to test the assumptions of tool tip distance to G54 as well as accuracy of the alignments. After these were adjusted the program was modified to create a simple part that would be rotated on all axes simultaneously. In Figure 6 you will see a MasterCAM screenshot of the modified hexagonal part. This part is a semi spherical shape with a name engraved across the surface. This program will use all axes to create the letters.

Figure 6 Name on Sphere



A piece of plastic was used to test the new program and to see if rotation of all axes would be executed. In Figure 7 a part is shown with a name engraved across a spherical shape.

When this program is executed, proper location of the tools as well as when the trunnion tilts will be closely observed so that any collisions can be avoided. Again wooden end mills were used and when the name engraving program was created it was noted that the Z distance was incorrect. This would not have been detected if a careful test run with the wooden tools had not been conducted. Once the proper Z distance for the engraving tool (center drill) was established then the wooden tool was replaced with a high speed bit.

Figure 7 Engraved Name on Part

CHAPTER 3 Issues with New Technology

Some of the issues related to bringing new technology onboard are discussed in this chapter. Items such as missing trunnion parameters, software upgrade issues, wrong retention knobs, and the learning curve and others were all part of the delayed the use of the machine. Over the course of nearly a year these problems were identified and corrected all the while normal operations of the rest of the machine shop and Mechanical Engineering Technology classes took place. Also, the machine tool reseller does not conduct training for multi axis machines. This training is passed on to the CAM reseller.

The first issue was that not all the trunnion parameters were put into the settings for the machine. When the technician from the Haas factory outlet in Greensboro set the trunnion in the machine, a list of on/off positions for the parameters was provided with the particular model of the trunnion. Part of the list was missing. This was not apparent until the fall semester when A90 was programmed into “MDI” or Manual Data Input that there was a problem. The machine would alarm out saying that this was over travel for the A axis. However, in “Handle Jog” mode the trunnion could be rotated past this point and also past the -90 degree point without any alarm messages. This problem was quickly fixed once the technicians were called in to check the machine trunnion to make sure the correct parameters were sent in. It was determined that a portion of the parameters had been cut off the end of the paper.

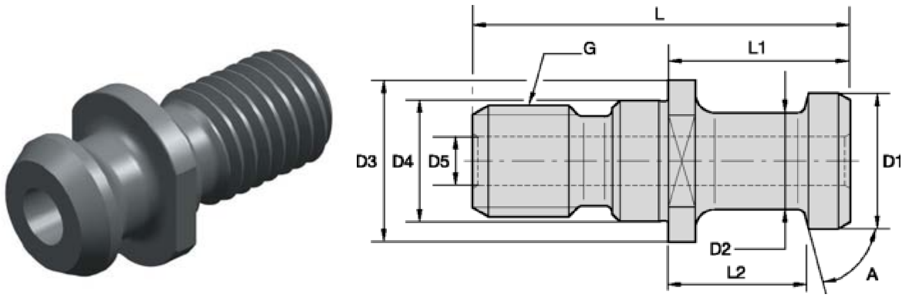
The second issue was with the software upgrade. All of the engineering software used at Mitchell Community College is upgraded every year including the MasterCAM software. However, up until the fall of 2011, no addition of multi axis tool paths had been added to the usual upgrade. The time for renewal for this software is every October because this is when the yearly subscription runs out for MasterCAM and when this was renewed a special emphasis was placed on the addition of the multi axis tool paths. The upgrade/renewal went into effect in

November of 2011. So until that time, the machine could not be programmed with the current level of software.

Still another issue involved hardware used on the machine. Tool holders were purchased for the machine so that the current tool holders used on the 3 axis could be kept with the older machine even though they would fit the new 5 axis. Figure 8 shows the assembly of the tool holder. Retention knobs are used to pull the tool holder up into the machine spindle. When this happens the tapered part of the tool holder is squeezed by the taper inside the machine spindle which increases the clamping pressure of the collet onto the tool. Figure 9 is a CAD drawing of a retention knob.

Figure 8 Old and New Tool holders

Figure 9 Retention Knobs



The next photo shows how the tool holder, nut, and an actual ball nose end mill will be assembled. The tool holder uses a collet to hold the end mill in place. Collets have the advantage in that they automatically center the tool with the Z axis of the machine spindle and they exert force evenly around the tool. They are also more balanced than the end mill holder from the old machine. End mill holders have two set screws that lock the end mill into place, this makes this type tool holder unbalanced and unsuitable for close tolerance machining at high speeds.

Figure 10 Tool Holder and Tool Assembly

CHAPTER 4 Learning Curve

The learning curve is steep for some people and for others who are genuinely interested it is not. How the information is presented and rehearsed also leads to how deep the information becomes imbedded. "Learning and retention are different. Learning involves the brain, the nervous system, and the environment, and the process by which their interplay acquires information and skills." (Sousa, 2006) Sometimes learning unfortunately does not include long term retention, however, when a hands on approach is used, the retention will be longer since more of the body's senses are used to learn the process. "Over the course of our lives, sight, hearing, and touch (including kinesthetic experiences) contribute the most."

Several training sessions were completed over the spring semester. The first session was in early March for three days. This was the introduction to multiaxis machining course for MasterCAM software and involved the demonstration of the various CAM tools found in the many layers of MasterCAM. Topics included in this first three day session included tool lead/lag, and tool point vector. Being able to control the motion of the tool seemed to be the focus of most of the training. Training was funded through customized training program 359. This is a fund set aside for internal training to build instructional capacity so that these skills can then be offered to students who would enroll in either a curriculum or continuing education course. The amount requested was $2000.00 for 6 training units. The first three sessions were during the first week of March and the remainder dispersed over April and May.

Mr. Jim Wakeford came to the Machining Lab at Mitchell Community College the 23rd of March to work with me and the machine. This is when part home was found out to be set in relation to the trunnion and not in relation to the part as is the case for a three axis machine. The center of rotation of the trunnion is G54 or also known as Part Home and will never change as long as the trunnion is never moved. The part to be machined has to float above this point as well as above the three jaw chuck for the machine to be able to accurately find and then proceed to machine the part. If only the machine had eyes then this process would not be needed.

CHAPTER 5 MAC 232 Advanced CNC Graphics

This is one of the capstone courses found in the Mechanical Engineering Technology Associate of Applied Science program at Mitchell Community College. The pre requisites are MEC 110 Introduction to CAD/CAM and MAC 124 CNC Milling. It is also very helpful if the student has had MEC 111 Machine Processes also known as manual machine shop. A portion of the syllabus is shown in figure 11.

Figure 11 MAC 232 Syllabus

SYLLABUS

Mitchell Community College
MAC 232: CNC Graphics Programming: Milling

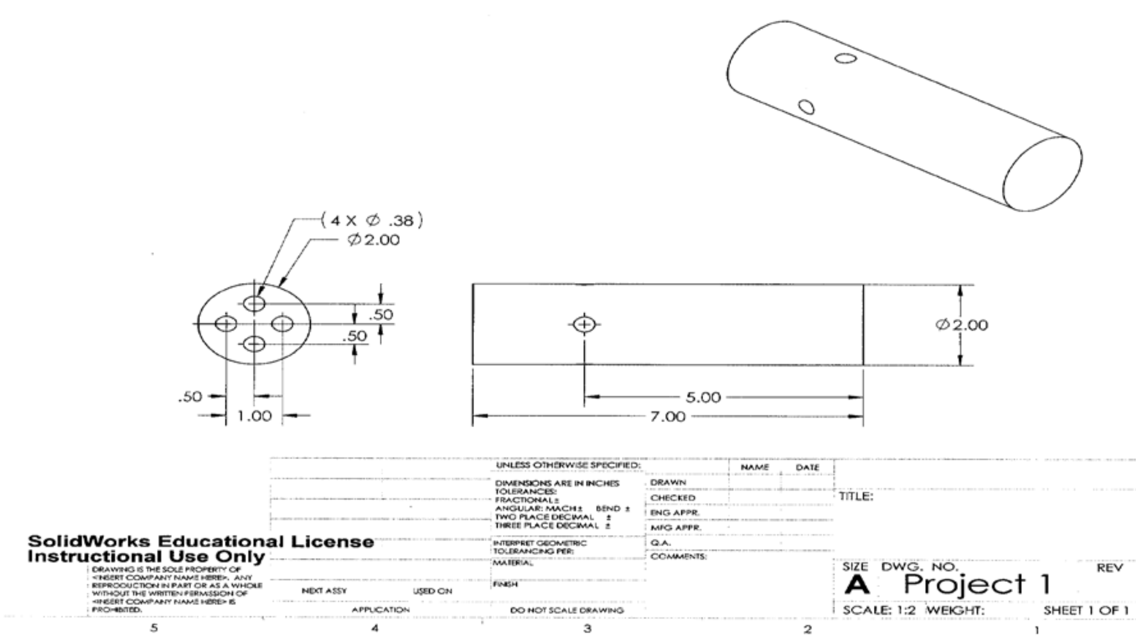
Institutional Credit Hours: 3 **Contact Hours Per Week: 5**
Prerequisites: MAC 121 or MAC 124 AND MEC 110 **Corequisites: None**

Instructor: Sharon Rouse srouse@mitchellcc.edu
Telephone: 704-878-3241
Office location: WFD 215
Office hours: See office door

Catalog Description: This course introduces Computer Numerical Control graphics programming and concepts for machining center applications. Emphasis is placed on developing a shape file in a graphics CAM system and transferring coded information from CAM graphics to the CNC milling center. Upon completion, students should be able to develop a complete job plan using CAM software to create a multi-axis CNC program.

Course Objectives: Students will be able to create a multi-axis Master CAM drawing, the related tool paths, and produce a multi axis part on the HAAS CNC 5 axis machining center.

A simple part made on the machine was the goal for this first semester. Students were allowed to use the MasterCAM Mill Level 3 for this class to further understand how 3D objects were to be made on the equipment. The first simple part is shown in Figure 12.



The issue with this part was that we did not understand how to properly locate it in relation to the center of rotation of the trunnion. When the machine rotated the part to a positive 90 degrees, the spindle did not move to the end of the part to drill the holes around the circumference. This was when Mr. Wakeford's help came into play with locating your part above the trunnion and chuck in the software and not to the actual part. However we were on the right track with understanding the capability of the machine in relation to rotation in the A and B axes.

CHAPTER 6 Conclusion

A simple part was made on the machine using all axes simultaneously and with the help of MasterCAM. The part is a modification of the hexagonal part that was produced some time back, however in this case all axes are employed to create the lettering on top of the part. In Figure 13, the simple 3D part is shown with lettering that wraps across the curved surface.

Figure 13 Name on Sphere

With the problems associated with bringing new technology onboard while a full load of other work must be done causes delays in implementation of the technology. Fortunately, management is aware that a person can only accomplish so much when there are many demands put on their time. The problems presented in the process are just part of the learning experience and will be forwarded to the students for their benefit once they are on their own jobs.

Until you in the moment of troubleshooting, you will only have a passing interest in a problem. It is when you have to find out the cause of a problem that you begin to learn other things associated with the machine tool or the software used to program it. In the end the trainee's learning experience is ingrained into long term memory due to the struggle to comprehend the subject.

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