Adding CNC Expands Engineering Course Options

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THREE years ago, a suggestion in passing changed my high school's technology curriculum forever. "Our classes should do more projects together," suggested Jeff Faria, a building contractor and veteran teacher at Hanover (MA) High School. Faria had created the school's woodworking curriculum 15 years earlier from the remnants of a previously defunct program. I had just been hired as a technical drawing/CAD instructor after recently receiving my undergraduate degree in mechanical engineering.

The ideas we bounced off each other in ensuing conversations greatly reminded me of the cutting edge program at a school I had attended, Plymouth (MA) North High School, where problem-solving skills and creative thinking were emphasized in the course of designing and fabricating projects to solve technical challenges.

Over the next year, Faria and I discussed and planned lessons that would make use of skills and tools from each of our existing programs.

Kevin Manning works on part of the robot's "weapon."

We decided to create a unified engineering course sequence in which students would gain exposure to the engineering design process from start to finish. As it turned out, key to our efforts would be getting our students involved in using computerized numerical control (CNC).

Introducing CNC

Another comment in passing from Faria would revolutionize our program: "A CNC mill would allow us to do things we never thought possible," Faria said, setting off a pursuit that would revolutionize our program. Superintendent Kristine Nash was surprised by our request to purchase CNC equipment but receptive to learning more. So Faria and I began our research.

CNC generally refers to machine tools whose operation is driven by a computer interfaced with the machine. CNC mills, lathes, and routers are common, but the technology is also found in plasma and laser cutters, water jets, sewing machines, and other machines.

CNC milling machines have been used in industry for decades. The control system eliminates the shortcomings of traditional milling, allowing for producing complex shapes and curves that are hard to achieve with a human operator, with the bonus of unparalleled precision and repeatability. In recent years, CNC equipment has become more accessible, and schools have integrated it into their curriculum. The equipment's educational benefits are as significant as its productivity gains.

In the course of conducting our re-

Hanover High's robot, "The Bull," was machined entirely with a CNC mill.

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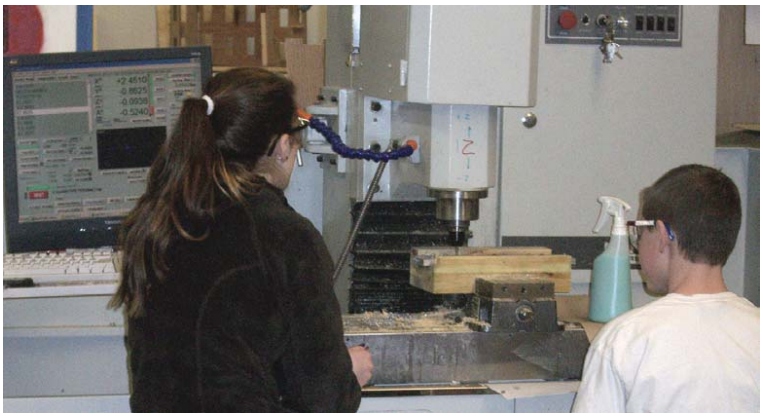
search, Faria and I found that our options seemed endless, but we finally settled on a Tormach PCNC 1100 mill. Faria described it as "the right combination of performance and price for our program." At the end of the budget year, funds were available and the machine was purchased.

Having a CNC mill has definitely advanced the capabilities of Hanover's Engineering Department. Sean Crowley, a senior and the pit crew chief of our robotics team noted that the team uses the mill to build 15-pound robotic warriors that compete against entries from other high schools in the Battlebots IQ robotics competition. Last year, the team finished fifth in the nation—its best finish ever.

"We used the CNC mill to make almost all of our parts. We built an entire robot in under a week," said Paulina Leech, a four-year member of the team and last year's MVP. Without the mill, the work would have taken months. "We were able to build it in under a week because we could run a program and work on other pieces at the same time," Leech added.



Pauline Leech and Conor Crowley look on while their G-code program runs.

Bill Packer, a student in our Engineering II course, describes part of the process: "After creating a drawing in CAD, I created a G-code program to mill it. I learned to use the machine quickly, and it helped me to understand the X, Y, and Z axes."

CNC equipment uses a computer language called G-code to communicate with the electronics, motors, and sensors that direct the motion of the machine. G code is a language based on the X, Y, Z Cartesian coordinate system that high school math classes revolve around. G code can be written manually or generated by a CAM program. Manually coding a program requires understanding those concepts and performing calculations, which is why students have to create a program themselves before using automated methods. ►

According to senior Paul Lyons, "This code poses a new challenge as we have never had to deal with this before. Through training, we have learned that every symbol and number sequence has a specific meaning. This means that we can make any specific part or piece that we want as long as we have the right code."

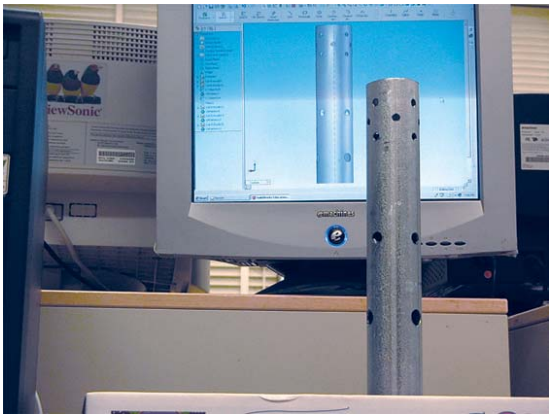
The author and Connor Grealish use the fourth axis to create a drive train component.

Students also learn the same machining concepts and processes that they would learn in using a traditional mill. Tom Reddish, co-caption of the robotics team, says he gained good hands-on experience with diverse metals and materials in the course of using a milling machine. "Learning that a slower feed rate is not always better when cutting through materials is something that you really can't grasp out of a book or article. Actually seeing and hearing how the material is cutting really gives you a better understanding of how the whole process works," Reddish added. "On top of cut speeds and plunge rates, you also learn about the different end mills you can use and how some work well for certain metals but not quite as well on other metals. When we were cutting our aluminum pieces, we had the leeway to use a two-flute or a four-flute end mill. However, when we purchased our titanium and attempted to cut it, we learned that we were going to need an eight- or 12-flute end mill. The four-flute didn't provide enough cutting surfaces to efficiently cut through the titanium."

Having CNC machinery opened students up to new possibilities for projects and new solutions for existing problems. Pat McIver said that "before having the CNC machine, the work done by the Engineering class could go little further than drawings on a computer and cutouts. Now we can add a variety of materials, enabling us to conduct more complex projects."

Additional Activities

Aside from in-class projects, our students have created personal projects, including a bookshelf speaker system, a Morris chair, a floor standing arcade console, and a functioning model jet engine. Making the model jet engine wouldn't have been possible without the CNC mill.



The flame tube for Greg MacDonald's jet engine was engineered in Solidworks and milled on the Tormach PCNC 1100.

"The most important part of the engine is the flame tube. It's primary purpose is to properly mix fuel with air for optimal combustion, and then hold the flame. The flame tube is a 1.75" electrical conduit with a specific hole pattern drilled into it. It is very important that these holes be drilled accurately, a feat that would have proved impossible for me without the aid of the CNC's fourth axis," said Greg MacDonald, who worked on the jet engine all year. Based on the turbine from an automotive turbo, the engine required him to machine many parts with high precision.

Community Support

Instrumental to the success of our Engineering program was the help we got from the community. After we received the mill, we contacted Mike Murray of Lakeside Design, a nearby machinist and Tormach consultant. Murray provided training sessions on use of the CNC mill and G code. He praised our students' efforts, noting that they learned quickly and adding, "I was very impressed with not only the kids but also the school administration's willingness to take on and learn this type of technology. It gives the students exposure to machine tool training, which in the past was only offered at vocational schools."

Murray also gave us other valuable assistance. Not only did he help get us up and running with the CNC mill, but he also reached out to his professional contacts to tell them about Hanover's new program and its value to them. Many made donations that helped advance our program even further. Murray noted, "When I started to ask for donations, I was quite impressed with the response I received. The common statement made by all parties is that this type of training is very much needed."