**What does math have to do with CNC Machining?**

**Video Link:** <https://youtu.be/1DIW11EiNcA>



**Lesson Plan**

**Teacher Note:** Please preview the entire video and pre-work the questions in order to anticipate students’ needs, misconceptions, and materials unique to your classroom.

Although the actual calculations in this video involve basic arithmetic (6th grade standards), the concepts surrounding the mathematics are at a higher level and will still be suitable for students up to a high school classroom. You will need to determine the background knowledge of your students regarding the following topics and decide the best method to support student understanding.

* Understand various rates.
	+ Revolutions per minute
	+ Surface Feet per minute
	+ Inches per minute
* Use formulas to evaluate expressions.

**Common Core Mathematical Content Standards (Wisconsin Labels)**

* **M.6.EE.A.2** Evaluate expressions at specific values of their variables. Include expressions that arise from formulas used in real-world problems. Perform arithmetic operations, including those involving whole number exponents, in the conventional order when there are no parentheses to specify a particular order (order of operations).

**Common Core Mathematical Practice Standards**

 1. Make sense of problems and persevere in solving them.

 2. Reason abstractly and quantitatively.

 3. Attend to precision.

**Company Information**

EMT International is an engineering and manufacturing company providing innovative solutions to the digital printing and label industries around the world. We have 160 employees (and counting) engaged in the design, assembly, and service of our contract and EMT/Rotocontrol product lines with facilities in Hobart, WI and Siek, Germany. As we continue to grow, we are always looking for positions in electrical and mechanical assembly, machining, service, and engineering.

**Summary**

Manufacturing companies such as EMT International rely on skilled workers who can operate machines such as CNC Lathes. The operators of these machines must understand tool geometry and the mathematics of speeds and feeds to ensure that well-made parts are created. In the video two machine operators need to determine the time it will take to run a particular part order for a customer.

**Differentiation**

* The questions on the student handout are scaffolded to meet the needs of students who may need extra support.
* Students who struggle may need additional discussion of the vocabulary used in the video.
* For those students who are very strong with their skills, consider having them try to figure out how the formulas in the video are derived.

**Pre-Activity Discussion**

* This video opens with two CNC Machine Operators discussing a part order that must be filled. They need to determine how long it will take to run the parts on a CNC Lathe. Our operators explain that they must determine information such as the speed in revolutions per minute and the feed rate in inches per minute to figure out the run time. Information like this requires them to use tool manufacturer guides and formulas before setting up parts to run. Otherwise, damage could occur and waste time and materials.
* Familiarize students with the vocabulary prior to the lesson as most terms are not familiar to people who do not work in this industry.
* **Vocabulary**
	+ **CNC –** Computer Numeric Control
	+ **CNC Lathe –** Programmable machine in which a part spins

in a turret. Cutting tools move into the spinning part to remove

material and create the desired shape.

* **Surface Feet per Minute (SFM) –** When a part rotates,

the entire surface along the circumference will touch the tool.

The higher the SFM the more frequently the surface comes in contact. Manufactures use this as a designation of the cutting speed.

* **RPM –** Revolutions per minute
* **IPM –** Inches per minute
* **IPR –** Inches per revolution
* **Spindle Speed –** Refers to the speed at which the part turns in RPMs
* **Table Feed –** Refers to the rate at which the tool advances into the part in IPMs.
* **Feed Rate –** Refers to the number of inches per revolution the tool advances and is determined from the manufacturer’s manual.

**Information Needed to Solve:**

* There are 50 parts to be made.
* Each part has a finished diameter of 2 inches.
* The manufacturer recommends a cutting speed of 800 ft/min
* The manufacture recommends a feed per tooth of .005 inches
* RPM = 3.82 x SFM x DIA
* Feed Rate (Vf) = z x n x Fz
	+ z is the number of cutting edges
	+ n is the spindle speed in RPM
	+ Fz is the feed per tooth in inches
* Machining Time (T) = (l x π x d)/(12 x Fn x Vc)
	+ l is the length of cut in inches.
	+ d is the turned diameter
	+ Fn is the feed rate in inches per revolution.
	+ Vc is the cutting speed in feet per minute.

**Part 1 (1:53 – 2:05)**

BREAK 1

* Students should individually or in groups do a search for what a CNC lathe is and how it works. This can be discussed as a whole group before the video or at this point.
* Students should give a quick response to the question of how tool movement is controlled.

**Part 2 (3:08 – 3:18)**

BREAK 2

* Given that the recommended cutting speed is 800 SFM and the cutting diameter is 2 inches, students should calculate the number of revolutions per minute on their own.

**Part 3 (4:08 – 4:19)**

BREAK 3

* Given the manufacturer’s value of .005 inches per tooth, students should calculate the table feed rate required for the job on their own.

**Part 4 (4:56 – 5:07)**

BREAK 4

* Have students calculate the time it will take to complete the parts given that the length is 5 inches and the diameter is 2 inches. We know that there are 50 pieces in the order. Students may benefit from working on this with a partner.

**Extension**

* Students can research stepper and servo motors to explain how they might work in a CNC machine.
* Students can use their knowledge of geometry to figure out why some of the formulas work the way they do. In particular they should figure out where the 3.82 constant comes from.
* Students can create a demonstration of the difference between SFM and RPM and explain how each might be used.

**Student Handout – What does math have to do with CNC Machining?**

Name(s):\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Pre-Activity Discussion:** *Notes on necessary background information.*

**Problem:** *Calculate the time required to turn the 50 parts that are 5” long and 2” in diameter.*

**Break 1**

* As a small group do a search for what a CNC Lathe is and how it works. List your information below.
* How is tool movement controlled in a CNC Lathe? (A, B, C, or D from the video).

**Break 2**

* Given that the recommended cutting speed is 800 SFM and the cutting diameter is 2 inches, calculate the number of revolutions per minute.

**Break 3**

* Given the manufacturer’s value of .005 inches per tooth, calculate the table feed rate required for the job.

**Break 4**

* Calculate the time it will take to complete the parts given that the length is 5 inches and the diameter is 2 inches. We know that there are 50 pieces in the order.

**Extension**

* Research stepper and servo motors to explain how they might work in a CNC machine.
* Use your knowledge of geometry to figure out why some of the formulas work the way they do.
	+ Ex. Figure out where the 3.82 constant comes from.
* Create a physical demonstration of the difference between SFM and RPM and explain how each might be used.

**Answer Key – What does math have to do with CNC Machining?**

**Pre-Activity Discussion:** *Notes on necessary background information.*

**Problem:** *Calculate the time required to turn the 50 parts that are 5” long and 2” in diameter.*

**Break 1**

* As a small group do a search for what a CNC Lathe is and how it works. List your information below.

***Sample: CNC stands for computer numerical control. A lathe is a machine that rotates a piece of material and a tool brought in contact with the moving part. The resulting movement cuts material from the part in order to shape it. A CNC lathe can be programmed to complete these actions automatically.***

* How is tool movement controlled in a CNC Lathe? (A, B, C, or D from the video).

***B. Tool position is guided by stepper or servo motors.***

**Break 2**

* Given that the recommended cutting speed is 800 SFM and the cutting diameter is 2 inches, calculate the number of revolutions per minute.

***RPM = 3.82 x SFM x Diameter***

 ***= 3.82 x 800 x 2***

 ***= 1528 rpm***

**Break 3**

* Given the manufacturer’s value of .005 inches per tooth, calculate the table feed rate required for the job.

***Vf = z x n x fz***

 ***= 1528 x 1 x .005***

 ***= 7.64***

**Break 4**

* Calculate the time it will take to complete the parts given that the length is 5 inches and the diameter is 2 inches. We know that there are 50 pieces in the order.

***T = (l x π x d) ÷ (12 x Fn x Vc)***

 ***= (5 x π x 2) ÷ (12 x .005 x 800)***

 ***= .65 minutes per part***

***50 x .65 = 32.5 minutes for the order.***

**Extension**

* Research stepper and servo motors to explain how they might work in a CNC machine.

**Solutions may include information regarding construction, advantages, disadvantages, applications, etc.**

* Use your knowledge of geometry to figure out why some of the formulas work the way they do.
	+ Ex. Figure out where the 3.82 constant comes from.

**When calculating the RPM in general, the 3.82 is actually just 12/π. Students can explore why this is. They can also spend time on the other formulas to see how they are derived.**

* Create a physical demonstration of the difference between SFM and RPM and explain how each might be used.

**Imagine a tire rotating. Surface Feet per minute refers to the total distance traveled by a point on the wheel as it turns. Revolutions per minute refers to the number of times the wheel rotates in one minute.**

**SFM = Circumference (in feet) x RPM**

