Contextualized Curriculum

for Adult Learners in Math and Literacy

How Fast Should it Spin?

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How Fast Should it Spin?

Industry Sector: Advanced Manufacturing
Content Area: Mathematics
Core Topic: Units

Expand All | Collapse All

Common Core State Standards

HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling.

HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

Adult Basic Education Standards

Number Sense

Standard N-1: Represent and use numbers in a variety of equivalent forms in contextual situations

Standard N-2: Understand meanings of operations and how they relate to one another

Standard N-3: Compute fluently and make reasonable estimates

Patterns and Functions in Algebra

Standard P-2: Articulate and represent number and data relationships using words, tables, graphs, rules, and equations

Standard P-3: Recognize and use algebraic symbols to model mathematical and contextual situations

Geometry and Measurement

Standard G-1: Use and apply geometric properties and relationships to describe the physical world and identify and analyze the characteristics of geometric figures.

Standard G-4: Understand measurable attributes of objects and the units, systems, and processes of measurement and apply appropriate techniques, tools, and formulas to determine measurements.

Industry Overview

Today's Manufacturing Workplace

A manufacturing renaissance is occurring in the United States. The United States is the largest manufacturing economy in the world, producing 21 percent of the goods manufactured across the globe. In addition to the 12 million Americans working directly in the manufacturing industry, manufacturing supports more than 6.5 million other jobs, thus accounting for nearly 17 percent of all private sector jobs in the United States. In 2010, the average U.S. manufacturing worker earned $77,186, including pay and benefits (the average in all industries was $56,436).[1]

While manufacturing jobs in Massachusetts have declined, as they have nationally, manufacturing is still a critical industry in this state and provides opportunities for good, high-paying jobs. In the Greater Boston area, most of the manufacturing jobs are in computer and electronics companies, and much of the state relies on manufacturing positions in these and other very high-tech areas, such as aerospace and biotechnology.[2]

Advanced manufacturing involves the use of computers and technology in the manufacture of products. While not all manufacturing companies use technological innovations in developing their products or processes, the competitive advantage of the United States in the manufacture of goods relies on technological innovations. This means that today's manufacturing workplace is usually highly technical, which accounts for the high-paying positions many workers in this field receive in compensation for their work. It also means that today's advanced manufacturing workplace is very different from many people's conceptions of factories and mills as dark, dirty, and unsafe. Today's advanced manufacturing facilities are usually bright, clean, and very safe, and the emphasis is on working efficiently—with as little waste as possible.

In the advanced manufacturing industry, there has been a marked shift from the traditional role of line workers to workers who demonstrate creativity and innovation. Innovation is a hallmark of the U.S. manufacturing industry, and key to maintaining its position in the global market since products can often be produced at a lower cost in developing countries. Critical-thinking, problem solving and reasoning are important components of the innovation process. Today's manufacturing workers are expected to formulate solutions to problems using critical thinking and reasoning skills while working independently and/or in teams.

1. http://www.nam.org/~/media/AF4039988F9241C09218152A709CD06D.ashx
2. http://www.bostonglobe.com/business/2012/05/08/high-end-factory-jobs-boston-paying-high-wages/3gZuNc6GywDGKoYNP2hnaO/story.html?camp=pm

Careers in Advanced Manufacturing

The manufacturing sector includes jobs related to planning, managing, and performing the processing of materials into intermediate or final products and related activities such as production planning and control, maintenance, and engineering. Thus, this industry includes not only those people who actually produce the manufactured goods, but also managers, maintenance staff, scientists and researchers, analysts, administrative personnel, and IT personnel.

Career Pathways

The manufacturing industry includes six career pathways:

- Production is the construction and assembly of parts and final products. People in these positions work in factories and mills, with machines, to make or assemble parts, construct components of parts (such as plastics), and print materials. Occupations in this pathway range from production helpers who move parts and materials around the factory, to numerical control machine operators

who run the computer-controlled machines that modify metal and plastic to create products, to manufacturing production technicians who oversee production.

- Manufacturing production process development occupations are involved in designing products and manufacturing processes. People in these occupations work with production workers to set up the machines and processes to develop new products. These occupations include engineers and production managers.

- Maintenance, installation and repair workers take care of products after they've been sold and delivered to customers—they install the products, perform maintenance on machines, tools, and equipment so that they work properly, and repair systems that are not performing adequately. Workers in this pathway include automotive technicians, automotive electronics installers, building maintenance workers, industrial electronics repairers, industrial machinery mechanics, millwrights, and small engine mechanics.

- Quality assurance is provided by quality control inspectors and technicians, who ensure that products both meet design standards and are of high quality.

- Logistics and inventory control workers ensure that those working in Production have the materials they need to complete their work. Workers in these occupations inventory materials and products, move materials to the line, and pack and ship finished products. Thus, they include production and planning clerks, and operators of moving machinery such as cranes and forklifts, and packers.

- Health, safety and environmental assurance occupations are focused on keeping the workplace safe by ensuring that workers are using equipment safely and that manufacturing processes are as safe as they can be. The also conduct investigations and conduct inspections.

Mathematics and Communication Skills Needed in Advanced Manufacturing

Mathematics and communication are key skills needed for success in today's high-performance advanced manufacturing workplaces. Mathematics is used in the advanced manufacturing industry to measure the amounts and sizes of materials and parts, create "recipes" used to manufacture man-made materials, and analyze data. Data analysis is critical at many levels of a manufacturing organization in order to ensure quality and to continuously improve both quality and processes. Today's manufacturing industry must operate extremely efficiently and produce very high-quality products in order to maintain competitiveness. Many front-line workers are involved in collecting data and working to improve quality and efficiency. Thus, in addition to basic mathematical calculations (which rarely involve simple whole numbers), workers are engaged in mathematical reasoning and solving problems using a variety of mathematical tools.

To succeed and move up the ladder in today's advanced manufacturing workplace, workers need reading skills to understand technical concepts, vocabulary, and to bring together information needed for a particular situation; to locate, organize, and document written information from various sources needed by co-workers and customers; and to locate written information needed by co-workers and customers. They need to use correct grammar, punctuation and terminology to write and edit documents and to develop and deliver formal and informal presentations using appropriate media to engage and inform audiences. In addition, they need to interpret verbal and nonverbal behaviors to enhance communication with co-workers and clients/participants; apply active listening skills to obtain and clarify information; and interpret and use information in tables, charts, and figures to support written and oral communications. They also must communicate with co-workers and customers using technology tools. As they move up the corporate ladder they will need to explain written organizational policies, rules and procedures to help employees perform their jobs.

Career Opportunities in Advanced Manufacturing with Education from Community Colleges

Massachusetts Community Colleges play an important role in preparing the state's citizens to take advantage of the career opportunities available in advanced manufacturing. Degree and certificate programs prepare students to enter advanced manufacturing occupations, including:

- production occupations, including people who work as assemblers (such as airplane assemblers), machine operators, machinists, systems operators, CNC machine tool operators, machine setters,

laminators/fabricators, metal and plastic workers, packers, molders, semiconductor processing operators, welders and solderers, tool and die makers, and other production workers;

- manufacturing production process development occupations, including numerical control tool programmers who write the programs that control machine tools and industrial production managers who plan and oversee production;

- maintenance, installation and repair occupations include automotive, electronics, and biotechnology technicians, industrial machinery mechanics, and millwrights (who install and maintain heavy equipment);

- quality assurance occupations including quality control technicians and inspectors.

Recent Career Opportunities in Massachusetts

The following is a sample of advanced manufacturing job listings in Massachusetts that require associate's degree or certificate:

- Manufacturing Engineering Technician, Randstad Corporation, Framingham, MA, [show]
- Quality Control Technician, QD Vision, Lexington, MA [show]
- Manufacturing Technican, Hologic, Marlborough, MA [show]

Employment Outlook for Advanced Manufacturing

Advanced manufacturing continues to be a high-growth industry, given the knowledge capital in the United States. However, the work in this industry is increasingly technical and requires far fewer workers as more tasks are automated. Entry-level positions in this industry require the same skills that only a select group of highly-experienced and well-paid workers once had. Unfortunately manufacturers find it difficult to fill these high-skill positions. A 2011 survey found that there is a persistent skills gap between the skills that are needed in the today's manufacturing workplace and the skills that candidates bring to the workforce.

Most of the advanced manufacturing companies in Massachusetts are small to mid-sized operations that employ smaller numbers of workers and rely on computer-operated machinery for production. While the numbers of workers are smaller than in the past, the more highly-skilled nature of the work means that these are high-paying jobs and provide workers with opportunities to grow through training and education and to be part of the effort to innovate.

Resources:

Advanced Manufacturing Industry

- National Council for Advanced Manufacturing
- Advanced Manufacturing
- Brookings: "Why Does Manufacturing Matter? Which Manufacturing Matters?" (2012)
- National Association of Manufacturers: "A Manufacturing Renaissance: Four Goals for Economic Growth" (2012)

Advanced Manufacturing Industry Outlook Information

- Bureau of Labor Statistics: Manufacturing Industry at a Glance
- Massachusetts Labor Market Data
- Massachusetts Career Information System

Careers in Advanced Manufacturing

- Massachusetts Career Information System
- Manufacturing Career Opportunities
- Manufacturing Career Pathways
- Industry Competency Model for Advanced Manufacturing shows the skills and knowledge needed to work in this industry

- National Association of State Directors of Career Technical Education Consortium's Common Career Technical Core
- National Association of State Directors of Career Technical Education Consortium's Knowledge and Skills: Manufacturing
- O*NET
- WorkKeys Occupational Profiles
- Manufacturing's Missing Generation
- A Career in Toolmaking or Machining Technologies: The Right Choice for Students, Community, & Country

Workplace Scenario (8th Grade Level)

You work at a small manufacturing company. You operate the computer numerical control (CNC) machine. This machine makes different types of tools, parts, and other objects. You must use math skills and reasoning to operate the machine. The parts it makes are of different shapes, sizes and weights. These are based on drawings. They are components of larger manufactured items. The components are then assembled. Examples include plastic parts used in cars or airplanes.

This profession requires a high level of accuracy. Parts have to be produced to the specifications. You need to interpret the blueprints. You must make a series of calculations to set up the machine. This requires a strong number sense. Sometimes you calculate volumes for the materials needed. Additionally, you must calculate the cutting speed. You also determine the size of the cutter to use. You calculate the angle and depth of the cut. You calculate how long it will take to create the required cut.

Workplace Scenario (High School Level)

You are a CNC Operator at a small manufacturing company in central Massachusetts. You operate the computer numerical control (CNC) machine, which makes different types of tools, machine parts, and other objects. In this position, you must use mathematical skills and reasoning to produce parts of varying shapes, sizes and weights. These are based on engineering drawings and computer controlled machines. They are components of larger manufactured items that are then assembled as part of the manufacturing process, such as various metal and plastic parts used in cars or airplanes.

This profession requires a high level of accuracy. Parts have to be accurately produced to the engineering specifications. You must make a series of correct calculations to set up the machine. To complete these operations you need a strong number sense. You also need important math skills such as interpreting blueprints, calculating volumes for the materials needed, and calculating numerical values based on formulas to guide the tool selection and set up of the machine. For example, you must calculate the cutting speed and size of the cutter to use. You may also need to use formulas to calculate the angle at which to cut the part, how deep to make the cut, and how long it will take to create the required cut.

View a video introduction to CNC Operation: http://www.youtube.com/watch?v=uEpjjeDMsPE

Core instructional context

Understanding units and how to calculate various properties such as speed, diameter, and rpm, are foundational skills for CNC operation, and transferable to a great many other professions.

Using correct units for measurement and calculation are critical life and workplace skills that are used frequently by students throughout their daily personal and working lives.

In advanced manufacturing jobs such as the CNC Operator highlighted in the scenario in this module, as well as jobs such as blending technicians, metallurgists, and other positions where ingredients or

parts are measured to create materials, accurate calculations are critical.

CNC Operators sculpt intricate parts out of a solid block of material. The properties of the resulting part are dependent on the use of correct equations and proper unit conversion. Not doing so will lead to poor quality materials and the potential rejection of materials by customers. Being able to make accurate calculations are skills that many employers find lacking in job applicants. Students seeking employment can find it very helpful to be able to demonstrate their abilities in applied algebra.

Worked Examples

Problem 1: Understanding Cutting Speed
This problem works with the **spindle** of the CNC machine, a spinning cylinder that rotates at vary high speeds in order to cut away excess material and "sculpt" the part . The spindle is also called the cutter.

Image source: http://buildyourcnc.com/SpindlesAndAccessories.aspx

Before using a spindle in a machine, the machinist will program how fast it will spin. This is usually measured in two properties: revolutions per minute (RPM), and cutting speed, or how fast one point along the spindle travels. This point is the cutting edge of the spindle, or cutter. Cutting speed is measured in surface feet per minute (SFM). While surface feet may sound like area, **it is the number of linear feet a point on a rotating object travels in one minute**. Different cutting speeds are recommended for different materials, and machinists follow the guidelines from the manufacturer. In this example, the cutter is cutting a block of aluminum.

Imagine that a point on a cutter travels 700 ft. in 2 minutes. How many surface feet per minute does the cutter travel? This is the cutting speed.

To solve, use an equation similar to an equation for finding the distance traveled by a vehicle or person.

Step 1: Cutting speed (CS) = distance (ft) ÷ time (min)

Step 2: CS = 700 ft ÷ 2 min

Step 3: CS = 350 SFM

Problem 2: Calculate RPM using Cutting Speed and Circumference
Machinists program the CNC machine with the cutting speed, which is typically provided as a recommendation by the manufacturer of the material, and the RPM. If the cutting speed is 350 SFM (surface feet per minute), how many revolutions does the spindle make to travel that distance in a minute? To answer this, you need to calculate the RPM, or revolutions per minute. If you know the circumference—the distance around the circle) of the cutter, you may use a formula to find the RPM. **If the circumference of the spindle is 10 inches and the cutting speed is 350 SFM, what is the RPM?**

Step 1: Use the formula to solve the problem:

RPM = cutting speed (SFM) ÷ circumference (ft)

Step 2: Convert cutting speed from feet to inches—the units must be the same in order to accurately calculate RPM. In Problem 4, students will be introduced to constants that machinists use to "build in" these conversions.

Cutting speed = 350 ft per min x 12 inches in a foot = 4200 in. per minute

Step 3: RPM = cutting speed (SFM) ÷ circumference (ft)
= 4200 SFM ÷ 10 in.
= 420

Step 4: Answer: RPM = 420

Problem 3: Introduction to diameter

CNC machines come with many different sized spindles or cutters, usually measured by the diameter. While you will notice a few details on both ends, the spindle is essentially a cylindrical object with two circular faces.

The **diameter** of a spindle's circular face is the length of the line that goes all the way across the circle and through the center. Diameter is directly related to circumference; the larger the diameter, the larger the circumference. The ratio of circumference to diameter is п, or 3.14. The line below represents diameter.

The circular face of a spindle has a diameter of 9 inches. What is its circumference?

Step 1: Circumference is ___ x diameter, so ___ x 9 = 28.26

Answer: The circumference of the spindle is 28.3 inches.

Problem 4: How and why machinists use a constant

Constants are numbers in an equation that do not change. Machinists are faced with a mathematical dilemma: cutting speed is measured in feet per minute, yet the diameters of the spindles are measured in inches. In Problem 2, the constant 12 was used to convert inches to feet, as there are always 12 inches in a foot

Another complexity is that RPM is calculated by dividing cutting speed by circumference — the distance around the circle — but the spindles are sized by their diameters.

So to find RPM, machinists need a constant that not only converts feet to inches, but that converts diameter to circumference. Building this constant into the equation simplifies the calculation. Let's take a look at how this constant is derived in the next problem.

The problem: What is the RPM if the cutting speed is 30 feet/min and the diameter is 5 inches?

In the previous examples, we used the formula below and had to first convert the cutting speed to inches to keep the units consistent:

RPM = cutting speed (SFM) ÷ circumference (in)

First, change the formula to "build in" the conversion of cutting speed from feet to inches:

Next, we can "build in" the conversion of diameter to circumference using π.

This equation could be simplified by putting our conversions that we built in (feet to inches and diameter to circumference) as a separate fraction:

Replace π with 3.14

Simplify the equation even further by dividing 12 by 3.14.

So our constant, which converts feet to inches and diameter to circumference, is 3.82. The solution to the problem:

The equation that CNC Machinists actually use to calculate RPM is below; the equation builds in all the conversions by using a constant of 3.82.

Contextualized learning activities

A. Read the Scenario

a. Begin this unit by playing an audio clip (3:22) from Michigan Public Radio, "[Meet the Machine that Makes Most of the Things in Your Life](#)." This short audio clip is engaging, explains what CNC machines do, and provides some interest around choosing this job.

b. Show students a video (:56), [Introduction to CNC Operation](#), so that they can visualize this kind of work.

c. Ask students to read the scenario in this module. Have students look for unfamiliar words or concepts and write those on the board.

B. Hands-on activities to develop conceptual understanding

Note: Many of the concepts in this module will be unfamiliar to students and hard to imagine. These hands-on activities help students develop a conceptual understanding of some of the more complex math such as RPM (revolutions per minute), rotational distance, and speed. Starting with a conceptual understanding will improve students' ability to understand the mathematical procedures and applications in this module.

1. Introduction to RPM and speed. Mark a spot on the wheel with some brightly colored tape that shows one point on the wheel. Set the timer for 15 seconds. Have students count the number of revolutions, and then have them multiply by 4 to get revolutions per minute. Explain that you are multiplying the number by 4 to get the number of revolutions over 60 seconds.

Using a measuring tape, demonstrate how to measure the circumference of the wheel in inches. Start at one point on the wheel and wind the measuring tape all around until it reaches the starting point. Tell them the circumference.

Explain that the circumference is the distance that one point on the wheel travels in ONE revolution. The speed can be found by multiplying the revolutions per minute by the circumference. Given the wheel's RPM, what is the speed of this point on the wheel?

Speed = RPM • circumference

If the speed is 300 inches per minute and the circumference is 10 inches), what is the RPM?

Step 1: Rearrange the equation:

![formula7]

Step 2: Solve.

![formula 8]

2. Introduction to rotational distance. Materials needed: tin cans and circle stickers.

Note: Rotational distance can be hard to imagine, so begin by letting students concretely visualize distance with a can that is rolling (rotating) across the floor. While in this example, the can is supposed to represent the cutter on the CNC machine, an actual cutter does not move by rolling on a surface.

a. Give students a tin can with a label and show them how to remove the label from the can's surface. Mark the section of the label that covers the entire circumference of the can by drawing a line parallel to the top or bottom edge of the label, equal in length to the circumference (this will help students "subtract" the part of the label that is overlapping). Explain that the circumference is the distance around the can or any circular object.

b. Next, put a circular sticker on the surface of the can to represent one point on the can. This circle represents one point on the can's surface.

Put the can on the floor and rotate it one complete revolution. Define circumference as the distance that one point on the can would travel with one revolution.

c. How many rotations does the can need to make to travel the length of the room?

d. Multiply circumference by the number of rotations to find out how far the center of the wheel traveled. This measurement is called **rotational distance**. Measure the length of its journey across the room to check your work.

3. Compare RPMs. Show two cans with different circumferences. Ask students:

a. Which one has the largest diameter? Which one has the smallest?

   Answer: the can with the larger circular face should have the larger diameter.

b. If you were to roll them across the floor and they were to reach the end of the room at the same time, which one would have a higher RPM? Why?

   Answer: The can with the smaller circumference would have the higher RPM.

Look for students' ability to express that speed and revolutions per minute (RPM) are different; it is a common misconception that RPM is the same as speed. The distinction is important in this problem, because the speed is the same for both cans (they get from one side of the room to the other side at the same time), but the RPMs for the cans are different. This is because the speed of the can moving across the floor is proportional to its spinning speed; if it is travelling at the same speed as the larger can, it needs to have the same spinning speed and because the circumference is smaller, more revolutions will occur in one minute.

4. Rotational Distance and Speed.

a. Refer back to the can and sticker; when the can rotates, whether it is stationary or actually moving, the point (sticker) is moving in a circular fashion. This is rotational motion. If this can were to roll across the room and make five complete revolutions doing it, how far would one **point** on the can travel?

   Answer: numbers will vary, but to find the answer, multiply number of revolutions x circumference of the can.

b. If a can rotates for two minutes at 50 RPM, how many revolutions does it make?

   Answer: it makes 100 revolutions in those two minutes.

c. If a can were to roll across a surface for four minutes at 50 RPM, and the circumference were 20 cm, how much distance would one point on the can travel? Follow the steps below to solve the problem:

   Step 1: Begin by calculating the revolutions.

   50 RPM x 4 minutes = 200 revolutions.

Step 2: The distance traveled with each revolution is the circumference, 20 cm. Multiply the revolutions (200) by circumference (20 cm) = 4,000 cm

Answer: The can travels 4000 cm and this is the rotational distance.

C. Apply concepts of rotational distance and RPM to CNC Machines.

The previous hands-on activities helped explore the concepts of rotational distance and RPM by looking at a rotating can. On a CNC machine, the rotating object is called the cutter. Machinists can still calculate its speed, as well as the rotational distance.

CNC cutter

Imagine that the cutter on the CNC machine is moving at a certain RPM as it sculpts a part. Setting the RPM of the cutter is critical. If the RPM is too high, it can cause errors with the cutting. If the RPM is too low, the cutting will be ineffective or inefficient.

Watch a video of a CNC machine working. Notice how the machine changes the cutter size at :37 and 1:14. Also notice how the cutter moves across the material; this is called the feed rate and machinists calculate this as well.
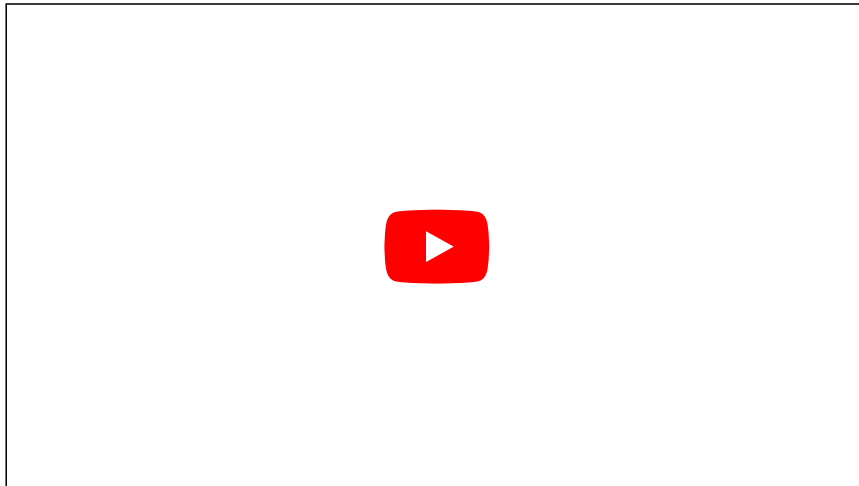
D. Worked Examples

Work the four problems in the Core Instructional Context section as a class.

E. Contextualized Problems (4)

Problem 1: Choose a cutter size

Your company is hired by a well-known American car company to fabricate a V8 engine for a prototype of a hybrid version of their top selling race car. You will be using a CNC state of the art machine tool and fabricating this 64-pound engine from a 386-pound block of aluminum alloy. To come out with a high quality engine, you need to use the optimum RPM so that the cutting is both efficient and error-free.

Video: http://www.youtube.com/watch?v=QsmiIeAkE-o

Your machine has a minimum RPM of 12,000, so you need to choose a cutter that works well at 12,000 RPM (give or take 4,000 RPM, though you don't want to go much higher than 12,000).

As a reminder, RPM is equal to the cutting speed divided by the circumference. Using the constant of 3.82 to build in the conversions, machinists use the following formula:

formula 9

a. Based on the data below, which is the best cutter to use for fabricating the V8 engine?

Cutter	Diameter (in.)	Recommended Cutting Speed
Cutter A	½	1582 SFM
Cutter B	¼	1106 SFM
Cutter C	¼	2650 SFM

Answer Key:

Cutter	Diameter (in.)	Recommended Cutting Speed	Answer (RPM)
Cutter A	½	1582 SFM	12,086 rev/min
Cutter B	¼	1106 SFM	16,900 rev/min
Cutter C	¼	2650 SFM	40,492 rev/min

Cutter A would work best.

b. You are at a stage of your project where you must keep cutting speed the same but increase the RPM. Remember that RPM depends on two things: cutting speed and the circumference, or distance around the cutter. How can you increase the RPM while keeping the same cutting speed?

> Answer: RPM is inversely proportional to circumference; in other words, as you increase circumference, RPM will decrease, and as you decrease circumference, RPM will increase. The solution is to use a spindle with a smaller circumference. Spindles are sized by diameter, so you would look for a spindle with a smaller diameter.

2. Calculate diameter of a cutter

In your shop, you are using a new spindle for the first time. After using it to sculpt an object, you find that its diameter has not been documented or marked on the spindle itself. Calculate the diameter of a spindle if RPM was 4584 and cutting speed (in SFM) was 600 ft / min. As a reminder, the formula to calculate RPM is:

formula 9

> Answer: 4584 = 600 x 3.82 ÷ diameter
> Diameter = .5000 in.

3. Calculate cutting speed.

You are working with a very delicate and rare aluminum alloy to produce a specialized (and very expensive) engine part. You need to make sure your exact cutting speed is no more than 600 ft per minute because you know that aluminum can shear at high cutting speeds; precision is very important because errors will be expensive. You know your rotating spindle has a diameter of 0.600 in, and you plan to set it running with an RPM of 3500 rev/min. Calculate surface feet per minute (SFM) using these values. As a reminder, the formula to calculate RPM is:

formula 9

> Answer: Cutting speed = 550 ft/min

4. Calculating revolutions per minute (RPM).

In a CNC machine, the cutting tool moves through the material at a specified rotational speed, defined in revolutions per minute (RPM).

You are cutting through aluminum to make some LED bike light housing. Aluminum is a tough material to cut through and can result in poor finishes and machine wear if your RPM is too high. Your machine

has a minimum RPM of 20,000, so you need a cutter that works well going at 20,000 RPM (give or take 4,000 RPM, though you don't want to go much higher than 20,000 because of aluminum's limits).

You have a cutter with a diameter of ¼ in. and a recommended cutting speed for this particular aluminum is 1500 SFM. Is this cutter sufficient for the job? As a reminder, the equation for finding RPM is below:

formula 9

RPM = (1500 SFM • 3.82) / 0.25 in.
= 5,730 / 0.25 in.

    Answer: RPM = 22,920 rev/min

Yes, this cutter's recommended RPM is just above 20,000 RPM, so it is sufficient.

Contextualized test items

1. You started an engine part late last week, but because of a bug with the CNC software and some temporary problems with your company's record keeping, you are unable to determine the exact spindle that you used to cut an engine part and your client needs the engine by the end of the week. Fortunately, you have data on the RPM and cutting speed of the last cut: 2292 RPM, 600 SFM. Which spindle should you use?

   A. 2292 RPM
   B. 3.82 in.
   C. ½ in.
   D. 1 in.

Answer: D, a 1 inch spindle or cutter

2. If SFM stays the same, what happens to RPM when you increase the size of the spindle or cutter?

   A. RPM stays the same.
   B. RPM gets smaller.
   C. RPM gets bigger.
   D. None of the above.

Answer: B, RPM gets smaller.

3. If two cutters of different sizes are turning at the same revolutions per minute, which cutter as a greater surface speed?

   A. The smaller cutter has a greater SFM or surface speed.
   B. The larger cutter has a greater SFM or surface speed.

Answer: B.

4. The constant 3.82 is important in working many CNC problems. Here is the formula:

formula 9

What does 3.82 refer to?

   A. π / 12
   B. 12
   C. π
   D. 12 / π

Answer: D.

Contextualized project

Your company has negotiated a better price for raw materials from a company in Canada. Their recommendations for cutting speeds for the raw materials are in metric, instead of standard. The CNC machine at your company, including all the sizes of cutters, uses standard measurements. To help out all the other CNC Operators on your team, your boss has asked you to create a nicely formatted conversion chart that can be posted in the shop and she reminds you to round the numbers. You've got one minute left on the battery of your cellphone, so you only have time to do one Internet search to help you make this table.

   a. What do you search for to help create this chart? Class discussion.
   b. Create the table as a class
   c. Students create word problems and share them.

   • Each student uses the chart to create a word problem and a worked solution.
   • The student gives the word problem without the solution to a partner.
   • Students solve each other's problems.
   • Students grade each other's solutions when complete.

Cutting Speeds for Materials Using a Plain High Speed Steel Cutter (Download table here)

Material Type	Meters per minute (MPM)	Surface feet per min (SFM)
Steel (tough)	15–18	
Mild steel	30–38	
Cast iron (medium)	18–24	
Alloy steels	20–37	
Carbon steels	21–40	
Free cutting steels	35–69>	
Stainless steels	23–40	
Bronzes	24–45	
Leaded steel	91	
Aluminum	75–105	
Brass	90–210	

   Answer:

   a. Answers will vary, but looking up the conversion of feet to meters would be very helpful.
   b. Answers for SFM appear in blue.

Cutting Speeds for Materials Using a Plain High Speed Steel Cutter (Download table here)

Material Type	Meters per minute (MPM	Surface feet per min (SFM)
Steel (tough)	15–18	50–60
Mild steel	30–38	100–125
Cast iron (medium)	18–24	60–80

Alloy steels	20–37	65–120
Carbon steels	21–40	70–130
Free cutting steels	35–69	115–225
Stainless steels	23–40	75–130
Bronzes	24–45	80–150
Leaded steel	91	300
Aluminum	75–105	250–350
Brass	90–210	300–700

Additional or extension activities, multimedia, readings and/or resources

Mill Safety Manual:
http://www.haascnc.com/doclib/manual/mill_safety.pdf

Machine Manual:
http://www.haascnc.com/doclib/manual/96-8000_english_mill_ap.pdf

What tools are used with a CNC Machine?
http://www.thomasnet.com/articles/custom-manufacturing-fabricating/cnc-machine-tools

CNC Machining Manual:
http://www.digitalfabrication.net/tutorials/AADPL_CNC_Manual_2010.pdf

Job description:
http://hiring.monster.com/hr/hr-best-practices/recruiting-hiring-advice/job-descriptions/cnc-operator-machinist-job-description-sample.aspx

What is CNC?
http://www.cncci.com/resources/articles/what%20is%20cnc.htm

Fundamentals of CNC (great diagrams)
http://www.mmsonline.com/articles/key-cnc-concept-1the-fundamentals-of-cnc

10 tips for CNC router aluminum cutting success
http://blog.cnccookbook.com/2012/03/27/10-tips-for-cnc-router-aluminum-cutting-success/

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