Key Concept

1

# Get Ready To Learn About CNC Turning Centers

*How much you need to prepare in order to get ready to learn about CNC turning centers is directly related to what you'll be doing with the machine. As you might expect, CNC programmers must know the most, since they will be developing the process by which the workpiece will be machined – and then creating a program that tells the machine how to perform each operation in the process. CNC setup people must know enough to get the machine ready to run a job. And CNC operators must know enough to keep the machine running properly through the entire production run.*

Frankly speaking, this Key Concept has little to do with CNC. Indeed, previous editions of our CNC-related texts have left it out entirely. Many technical schools consider the material presented here as prerequisite to learning about CNC. We tend to agree.

However, more and more people are entering the field of CNC with little or no previous experience in the shop environment. Without at least a cursory understanding of the topics presented in this Key Concept, upcoming lessons won't make much sense. For this reason, we include some very important introductory information in Key Concept number one.

Keep in mind that we have included just enough information about basic machining practices to get you started. We are *not* implying that this material will take the place of formal training in each related topic. Indeed, we are simply scratching the surface of each topic. If you have no previous shop experience, this material should provide enough information so that you will understand the presentations in upcoming lessons. On the other hand, if you have extensive shop experience, you can skim – maybe even skip – this entire Key Concept.

Key Concept Number one is made up of two lessons:

- Lesson 1: Basic machining practices required for CNC turning centers
- Lesson 2: What does a CNC turning center do?

In Lesson One, we cover five different topics:

1) Shop safety
2) Shop math
3) Blueprint reading
4) Tolerance interpretation
5) Measuring tools

In Lesson Two, we introduce the machining operations that a CNC turning center is designed to perform along with the cutting tools that are used to perform them. We divide machining operations into two categories, internal machining operations and external machining operations.

***Lesson 1***

# Basic Machining Practices Required For CNC Turning Centers

*As we have stated, the more a person knows about the basic machining practices that apply to CNC turning centers, the easier it will be to become a proficient setup person or operator. We cannot over stress the importance of understanding shop practices needed for successful turning center use.*

In this lesson, we introduce you to some of the most important principles you must understand *before* you begin learning about CNC turning center usage. The more you know about these topics, the easier it will be to learn to program, setup, or operate a CNC turning center.

There are five basic-machining-practice-related topics discussed in this lesson:

- Shop safety
- Shop math
- Blueprint reading
- Tolerance interpretation
- Measuring tools

Every single one of these topics could probably fill a manual larger than this one. So keep in mind that we are merely *introducing* you to each topic. Our intention is to provide enough information so that a newcomer to the machine shop environment will understand the presentations made throughout this text. But this will not be enough to fully master any of these topics.

If you are a novice, you will surely need more than this text offers about basic machining practices. At the very least, you will need the help of an experienced machinist when you begin working in the shop. You can also learn more by reading books on each of these topics – or you can attend related courses offered by technical schools.

## Shop Safety

A machine shop is a very dangerous place. There are hazards everywhere – and you must be very careful with everything you do and everywhere you go. While we offer some basic suggestions for keeping safe, we cannot possibly address every hazard in a machine shop. Most companies provide safety instruction as part of the orientation for new-hires. We bow to an experienced person in your company or school to provide more specific safety instruction than what we show in this text. But at least this presentation should make you aware of some of the most important safety issues.

### Safety equipment

**Protective eyewear** – most shops demand that you wear safety glasses at all times when you are in the shop – regardless of whether you are actually working on a machine or not. Most companies have signs on every shop entry door that say: **"Safety glasses required beyond this point."** In areas where debris may be flying everywhere (like welding and grinding departments), people are often required to wear full-face shields.

**Clothing** – The clothing you wear when working in a machine shop has an impact on your safety. Most shops require that you wear close-fitting long sleeve shirts and long pants (no tee-shirts or shorts) to protect your arms and legs from simple hazards. Don't wear any loose fitting clothes that could get snagged or hooked in the shop – or worse – grabbed by a moving machine part. Neck ties are banned from most

***Lesson 2***

## What Does A CNC Turning Center Do?

*A CNC turning center is one of the most popular types of metal cutting CNC machines because it is designed to perform common, yet important, types of machining operations. It is important to understand these machining operations in order to properly use a CNC turning center.*

In this lesson, we will describe the function of CNC turning centers. We will start by comparing CNC turning centers to other types of machines with which you may have some experience – or at least which you may have heard of or be acquainted with. Next, we'll show the three most common applications for lathe work. We will then introduce the cutting conditions that are related to machining operations. Finally, we will describe – in detail – the most basic kinds of machining operations that can be done on turning centers, including external machining operations and internal machining operations. At the completion of this lesson, you will know what a CNC turning center is designed to do.

### Comparing a CNC turning center to other types of machines

CNC turning centers replace certain *conventional* machine tools. While you may not have experience with CNC turning centers, you may have – at the very least – heard of one of the conventional machines they replace: a lathe. You probably know what a lathe is and/or have seen one in use. If so, you know that the primary function of a lathe is to remove material from a rotating workpiece with a relatively stationary cutting tool.

If you've been in your high school's wood shop, you've probably seen a wood lathe. The next illustration shows one.

**Wood lathe**

With a wood lathe, the (wooden) workpiece is held, supported, and rotated by the lathe's spindle – usually in some kind of chuck or centering device. The operator uses a hand-held cutting tool to gently shave or scrape material – in the form of wood chips – from the workpiece. Notice that the support for the cutting tool is literally in the operator's hands. While there is a tool rest used to support the tool and help keep it steady, the operator completely manipulates the cutting tool to remove material from the workpiece.

With a metal-cutting lathe, by comparison, the cutting tool is fully supported by the machine. The operator will turn cranks and handwheels to cause the cutting tool to move.

Face work done on a wood lathe

The pressures related to cutting metal are *much* greater than they are for woodworking. For this reason, a metal-cutting lathe must be much more rigid in order to properly stabilize the workpiece and the cutting tool. The next illustration shows the most popular form of metal-cutting lathe called an *engine lathe*.

Key Concept

2

# Know Your Machine From An Operator's Viewpoint

*As a setup person or operator, you must be comfortable with the machine you'll be running. You must know its basic configuration, its main components, its buttons and switches – and in general – the things you must do to make it function.*

As stated, Key Concept number one is very important, but has little to do with CNC and everything to do with *prerequisites* for learning CNC. If you are an experienced machinist, you probably skimmed Key Concept number one - or skipped it all together.

Key Concept number two begins our discussion of CNC related topics. We will address the things you must know about a CNC turning center in order to begin using it. We will be describing the machine from the perspective of a setup person or operator.

It may be helpful to know that CNC programmers tend to view certain aspects of the machine somewhat differently than setup people and operators do, which can lead to some confusion. We'll be sure to point out these differences throughout this Key Concept so you'll be ready for them.

Frankly speaking, a CNC programmer doesn't have to know all that much about the machine itself in order to program it. By comparison, a setup person or operator must become quite intimate with the machine – knowing all of its buttons and switches, as well as many important operating procedures.

Key Concept number two is made up of four lessons:

3: General flow of the CNC process
4: Machine configurations
5: Buttons and switches on the control panels
6: Key operation procedures

## The need for hands-on experience

As stated in the Preface for this text, hands-on experience is extremely important to fully mastering CNC turning center setup and operation. But unfortunately, no text can provide hands-on experience. If you are using this text as part of a course you are taking at a technical school, hopefully there are machines available for practicing what you learn in class. *We cannot overstate the importance of hands-on experience* – experience we cannot provide in this text. That said, we can provide *all of the principles* needed to set up and run CNC turning centers.

A CNC setup person and/or operator *must* spend time at the CNC machine to fully master tasks related to setting and running production on a CNC turning center. But before a person can spend any meaningful time at the machine, they *must* understand the concepts related to setting up and running the CNC machine. Without an understanding of the material presented from this point in the text, machine functions will have no meaning.

***Lesson 3***

# General Flow Of The CNC Process

*The tasks of programming, setup, and operation are but three of the things that must be done in order to actually get a CNC job up and running. It really helps to understand how these tasks fit into the bigger picture of a company's manufacturing environment.*

CNC machine tools are being used by all sorts of companies. Indeed, if a company manufacturers anything, it is likely that they are using at least some CNC machine tools. With the diversity of companies and applications, there comes diversity with what is expected of CNC people. Understanding where your company fits in to this diverse group should help you understand what will be expected of you.

## Companies that use CNC turning centers

There are many factors that contribute to how a CNC-using company applies its CNC turning centers. These factors include (among others) lot sizes, lead times, percentage of new jobs, size of tolerances held, materials machined, and company type. The most important of these factors is company type.

When it comes right down to it, there are only four types of companies that use CNC machine tools:

- ✍ **Product producing companies** – get revenue from the sale of a product
- ✍ **Workpiece producing companies** – (also called job-shops or contract-shops) get revenue from the sale of workpieces to product producing companies
- ✍ **Tooling producing companies** – get revenue from the sale of manufacturing tooling (fixtures, jigs, molds, dies, gauges, cutting tools, etc.) to product producing and workpiece producing companies
- ✍ **Prototype producing companies** – get revenue from the sale of prototypes to product producing companies

There are also overlaps in company type. For example, some product producing companies have a tool-room in which CNC machine tools are used – or they may have a research and development department that produces prototypes. Some workpiece producing or tooling producing companies have a product of their own.

While there will be exceptions to what we say here, some pretty good generalizations can be made based upon the company type alone, especially when it comes to what CNC people will be doing.

Product producing companies tend to have more resources than workpiece producing, tooling producing, and prototype producing companies. Since their profit is one step removed from manufacturing (a product won't come to market unless the company can make a profit), they tend to engineer all facets of the manufacturing environment. For this reason, they commonly break up the tasks related to CNC machine tool usage. People will specialize in the tasks they perform.

This will maximize machine tool utilization. It ensures that machines are running for as high a percentage of time as possible. Many CNC tasks will be performed while the machine is running production (like programming for upcoming jobs, gathering components needed for future setups, and assembling cutting tools, among others). So while a CNC operator is running a job on a CNC machine, other people are getting ready to run the next (and other upcoming) jobs. Again, this minimizes the amount of time that the CNC turning center is down between production runs.

***Lesson 4***

# Machine Configurations

*While you don't have to be a machine designer in order to run a CNC turning center, it helps to understand the configuration of the machine/s you'll be working with. At the very least, you must be able to recognize the major components and be able to identify the moving components (called axes).*

Most beginners tend to be a little intimidated when they see a turning center in operation for the first time. Admittedly, there will be a number of new functions to learn. The first point to make is that you must not let the machine intimidate you. As you go along in this text, you will find that a turning center is very logical and is almost easy to understand with proper instruction.

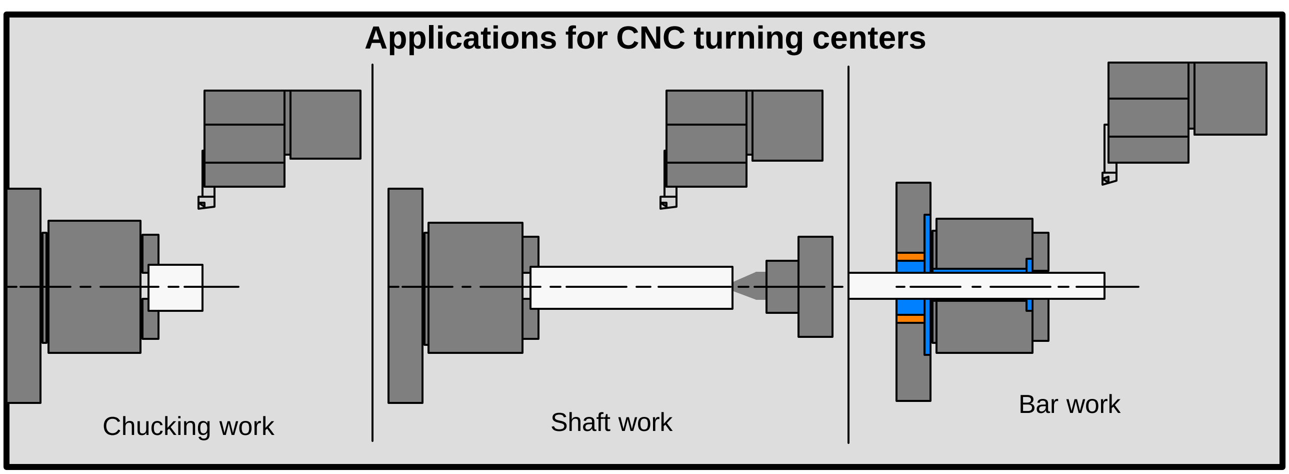
You can think of any CNC machine as being little more than the standard type of equipment it is replacing with very sophisticated and automatic motion control added. Instead of activating things manually by hand-wheels and manual labor, you will be preparing a *program* that tells the machine what to do. Virtually anything that needs to be done on a true CNC turning center can be activated through a program – meaning anything you need the machine to do can be commanded in a program.

## Types of CNC turning centers

There are several types of CNC turning centers. While at first glance there may appear to be substantial differences among the various types, all turning centers share several commonalities. We'll begin by describing the most popular type of CNC turning center – the *universal style slant bed turning center.* Because it is so popular, this is the machine type we will use for all examples in this text. We will then introduce several other types of turning centers, comparing them to the universal style slant bed turning center.

### *Universal style slant bed turning center*

This style of turning center is called a *universal style* turning center because it can perform all three forms of turning applications – chucking work, shaft work, and bar work. This explains why it is the most popular type of turning center – it provides the most flexibility to CNC turning center users.




When raw material comes to the machine in the form of short slugs (like round bars cut to length), the application is called chucking (or chucker) work. The raw material is secured solely by the workholding device (commonly a three-jaw chuck).

With longer slugs (longer than about three to four times the raw material diameter), the workholding device by itself will not be sufficient to secure the workpiece for machining. For these applications, some form of

***Lesson 5***

# Buttons And Switches On The Operation Panels

*While there are many buttons and switches on a CNC turning center, you must try to learn the reason why each one exists. If you don't, you may be overlooking a helpful – if not necessary – machine function. Worse, you may have a switch in the wrong position and not even know it.*

You now know the configurations for the most popular types of CNC turning centers. You know the most basic components, the axes, and the programmable functions. However, we have not addressed some very important machine components – the operation panels. These panels provide the access you need to activate machine functions, and are the topic of this lesson.

*A proficient setup person or operator knows the function of* ***all*** *buttons and switches* on their machine/s. While some may be seldom or never used, you must not consider yourself fully capable of running a machine until you know the function of all buttons and switches. If we don't cover a given button or switch in this text, ask someone in your company what it is – or look it up in the operation manual. Don't stop until you know why *every* button and switch is on your turning center.

If you are just starting out, this may be quite a challenge. You will be striving just to learn the most important buttons and switches. Learning all buttons and switches may seem like too much to ask. While we sympathize, we cannot stress enough the importance of learning all of the access you have to activate machine functions. Again, don't stop until you know all the buttons and switches on your machine/s.

You may find that some, if not most, people in your company do not know the function of all buttons and switches. When you finish this challenge, you may be the only one who does!

## The two most important operation panels

Most turning centers have at least two distinct operation panels. We'll be calling them the *control panel* (designed by the control manufacturer) and the *machine panel* (designed by the machine tool builder).

For turning centers that have a Fanuc control (Fanuc is by far the most popular control in the industry), the control panel will be remarkably similar from one turning center to the next. Indeed there are few variations, even among different Fanuc control models.

But since the machine panel is designed by the machine tool builder, turning centers that have been manufactured by different machine tool builders will have substantially different machine panels. To compound this problem, machine tool builders can't seem to agree on the specific functions needed by CNC setup people and operators to run their machines. So one machine may have an important button or switch while another may not.

While we can be pretty specific about the function of buttons and switches found on the (Fanuc) control panel, we will be a little vague about machine panel buttons and switches. Also, there may be buttons and switches on your turning center's machine panel that we do not cover in this text. If you find one, be sure to ask an experienced person or reference the machine tool builder's operation manual to determine the function for the button or switch.

*Lesson 6*

## The Key Operation Procedures

*Step-by-step procedures can keep you from having to memorize every function that you must perform on your CNC turning center. You will soon memorize procedures for task that you perform on a regular basis – but written procedures will always help you perform lesser used tasks.*

While you have been introduced to the various buttons and switches on a typical turning center, it is unlikely that you have yet memorized them all. It is also unlikely that you know the appropriate order by which you should press buttons and activate switches to do anything of importance on the machine.

For example, think of what it takes to perform one of the most basic tasks a setup person or operator must do on a regular basis – to power up the machine. Just because you know the related buttons and switches, does not mean you know the step-by-step *procedure* needed to turn on a CNC turning center. The procedure for a given turning center might look something like:

- ? Step 1: Turn on the main breaker (in back of the machine).
- ? Step 2: Press the power on button on the control panel.
- ? Step 3: Press the hydraulic system on button on the machine panel.
- ? Step 4: Follow the procedure to do a zero return.

With such a procedure, turning on the machine is not at all difficult. While you should still know the function of the related buttons and switches, this procedure provides you with sequential order (steps) you need. And similar procedures for other important tasks will be just as easy to follow (if you have them).

Admittedly, the most often used procedures will be soon memorized – and because most experienced setup people and operators have them memorized, they haven't written them down. And unfortunately, most companies don't have a written set of procedures for their CNC machines. Though this may be the case, nothing stops *you* from developing a written set of procedures for yourself. While you'll need the help of an experienced person, you can easily develop a set of procedures that will help you (and others) remember the steps necessary to do just about anything on the machine.

We divide the procedures needed to run a CNC turning center into five categories:

- ✍Manual procedures
- ✍Setup procedures
- ✍Manual data input (MDI) procedures
- ✍Program editing procedures
- ✍Program operation procedures

Here are specific procedures that we recommend you write down in each category:

**Manual procedures:**

To power up the machine
To do a manual zero return
To manually start the spindle
To manually jog the axes
To use the handwheel
To manually index the turret
To load tools into the turret

Key Concept

3

# Know The Compensation Types

*CNC turning centers provide three kinds of compensation to help you deal with tooling related issues. In essence, each compensation type allows a CNC programmer to create complete program without having to know every detail about the tooling needed for the job. During setup, the setup person will measure and enter certain tooling-related information into the machine – again – separate from the program.*

You should now have a pretty good understanding of the physical attributes of a CNC turning center. You know the machine's components, axes, and have been introduced to the most important buttons and switches. And you know that many of the things you will be doing on the machine require that you follow step-by-step procedures.

In Key Concept number three, we will be studying some functions that help you deal with the *tooling* related to a job – work holding devices and cutting tools. You now know many of the machining operations that can be performed on a CNC turning center (from Key Concept number one), as well as the cutting tools that are used to perform these operations. Some of the setup tasks that are related to cutting tools may be pretty obvious. Cutting tools must, for instance, be assembled and placed into the machine's turret.

Other things you must do with cutting tools may not be so obvious – at least not to a CNC newcomer. For example, the CNC machine must be told the position of every cutting tool – meaning each tool's position must be measured during setup. For some cutting tools, like single point tools that perform finishing operations, the tool nose radius must be determined.

We will also be taking a close look at *workholding devices*. As you know from Key Concept number one, a workholding device holds the workpiece during the CNC cycle. The most common example is a *three-jaw chuck*.

As with cutting tools, there are some pretty obvious tasks that must be performed with workholding devices. The chuck must, for instance, be mounted on the machine's spindle and top tooling (jaws) must be clamped to the chuck's master jaws. Other tasks are not so obvious. The machine must be told where the workpiece is located in the jaw.

With each of these lesser obvious tasks, there is a related form of *compensation*. And the focus of Key Concept number three will be to help you understand the compensation types.

Key Concept Number Three is made up of four lessons:

7: Introduction to compensation
8: Geometry offsets
9: Wear offsets
10: Tool nose radius compensation

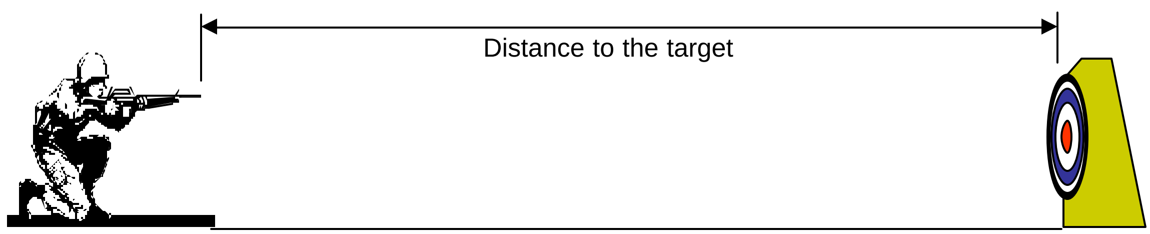
***Lesson 7***

# Introduction To Compensation

*An airplane pilot must compensate for wind direction and velocity when setting a heading. A race-car driver must compensate for track conditions as they negotiate a turn. A marksman must compensate for the distance to the target when firing a rifle. And a CNC programmer must compensate for certain tooling-related concerns as programs are written. Setup people and operators must address these compensations – which in turn – will marry the CNC program to the physical setup that is being made.*

## What is compensation and why is it needed?

When you compensate for something, you are allowing for some unpredictable (or nearly unpredictable) variation. A *race car driver* must compensate for the condition of the race track before a curve can be negotiated. In this case, the unpredictable variation is the condition of the track. An *airplane pilot* must compensate for the wind direction and velocity before a heading can be set. For them, wind direction and velocity are the unpredictable variations. A *marksman* must compensate for the distance to the target before a shot can be fired – and the distance to the target is the unpredictable variation. The marksman analogy is remarkably similar to what happens with most forms of CNC compensation. Let's take it further…




Before a marksman can fire a rifle, they must judge the distance to the target. If the target is judged to be fifty yards away, the sight on the rifle will be adjusted accordingly. When the marksman adjusts the sight, they are *compensating for the distance to the target*. But even after this preliminary adjustment and before the first shot is fired, the marksman cannot be *absolutely* sure that the sight is adjusted perfectly. If they've incorrectly judged the distance – or if some other variation (like wind) affects the sight adjustment – the first shot will not be perfectly in the center of the target.

After the first shot is fired, the marksman will know more. If the shot is not perfectly centered, another adjustment will be needed. And the second shot will be closer to the center of the target than the first. Depending upon the skill of the marksman, it might be necessary to repeat this process until the sight is perfectly adjusted.

With *all* forms of CNC compensation, the setup person will do their best to determine the compensation values needed to perfectly machine the workpiece (just as the marksman does their best in judging the distance to the target and adjusting the sight). But until machining actually occurs, the setup person cannot be sure that their initial compensation values are correct. After machining, they may find that another variation (like tool pressure) is causing the initial adjustment to be incorrect. Depending upon the tolerances for the surfaces being machined, a second adjustment may be required. After this adjustment, machining will be more precise.

***Lesson 8***

# Geometry Offsets And Assigning Program Zero

*The programmer will choose an origin for the program – which is called the program zero point. While the use of a program zero point simplifies the task of programming; it is usually the setup person who must determine where the program zero point is located in the setup – and who must enter this position for each cutting tool in geometry offsets.*

You know that a CNC turning center has two linear axes: X and Z. The CNC program tells the machine how to move these axes in a way that causes a cutting tool to machine the workpiece. To this end, the programmer specifies a series of *coordinates* through which the tool will move.

Coordinates are simply positions specified within the program. Think of the global positioning satellite (GPS) system in an automobile. It works by monitoring the car's current position on the earth. And this position is specified with coordinates – using longitude and latitude. With CNC machines, coordinates are specified in each of the machine's axes to cause a positioning movement within the machine's travel limits. Consider these X and Z coordinates:

X3.2 Z0.0

These coordinates may be specifying the position in each axis (X and Z) to which a finish facing tool must move prior to facing a 3.0 inch diameter workpiece. When this command is completed, the tip of the cutting tool will be ready to finish face the workpiece. But in order to make the cutting tool move to this position, the machine must know the *origin* for the coordinates – that is, the location from which all of the coordinates are taken. In CNC terms, we call this origin location the *program zero point*.

## How is the program zero point determined?

The programmer determines the program zero point location. Frankly speaking, program zero could be placed in just about *any* location. As long as the coordinates used in the program are specified from the program zero point, the program will function properly. Though this is the case, the *wise* selection of the program zero point will make programming much easier. It will also make it easier for the setup person.

### In X

Program zero in the X axis is *always* placed at the spindle/workpiece center. And all X coordinates are specified in diameter. Once program zero is assigned for the X axis (we'll show how later in this lesson), an X coordinate of X3.2 will make the cutting tool move to a *diameter* of 3.2 inches (assuming the Imperial [inch] measurement system is being used).

### In Z

Most programmers place the program zero point in the Z axis at the right end of the finished workpiece. This is the end opposite the work holding device. The next illustration shows an example of program zero placement based upon these methods.

*Lesson 9*

## Wear Offsets

*This compensation type allows the setup person or operator to deal with minor size variations as workpieces are machined. While many CNC people (somewhat inappropriately) use wear offsets to compensate for minor setup imperfections and tool pressure, the major application for wear offsets is to compensate for tool wear during a cutting tool's life.*

You know that the tolerances commonly held on CNC turning centers are quite small. It is not unusual to see at least one overall tolerance of under 0.001 inch (0.254 mm) on turned workpieces.

You also know that each cutting tool has its own program zero assignment – and that there are several ways to assign program zero. And you know that unless you are using a properly calibrated tool touch off probe, mistakes with program zero assignment – even minor ones – as well as the effects of tool pressure, make it difficult to *perfectly* assign program zero. That is, even after program zero is assigned, there is no guarantee that every tool will machine the workpiece perfectly – or even within specified tolerances. The tighter the tolerances you must hold, the greater the potential there will be for sizing problems.

*Wear offsets provide a way to make minor adjustments when machined surfaces are not within their tolerance bands – or when they're close to a tolerance limit.*

There are at least four times when a typical CNC setup person or operator will use wear offsets:

- ✍ **During setup and after mounting a cutting tool in the turret** - After machining with the new tool, if the setup person discovers that the cutting tool has not machined a surface within the tolerance band, or if the surface is close to a tolerance limit, they can change a wear offset to make the needed adjustment.
- ✍ **When trial machining** – Trial machining is done when the setup person or operator is worried that a cutting tool (that has just been placed in the turret) will not machine within the tolerance band. Wear offsets are commonly used with which to make trial machining adjustments (Remember, if you are using a properly calibrated tool touch off probe, you shouldn't need to trial machine.)
- ✍ **When compensating for tool wear** – As a cutting tool wears, it will cause the surfaces it machines to grow or shrink in size. Wear offsets are used to keep cutting tools machining on-size for their entire lives.
- ✍ **After a dull tool is replaced** – Again, during a cutting tool's life, tool wear commonly causes the need for sizing adjustments in wear offsets. When a dull tool is replaced with a new one, the wear offset must be set back to its initial value – otherwise the new tool will machine too much material from the workpiece.

In Lesson One there is a lengthy presentation about *tolerance interpretation*. From this presentation, you know that *every* dimension has a tolerance. You know that each tolerance will have a high limit (largest acceptable dimension), a low limit (smallest acceptable dimension), and a mean value (the dimension right in the middle of the tolerance band.

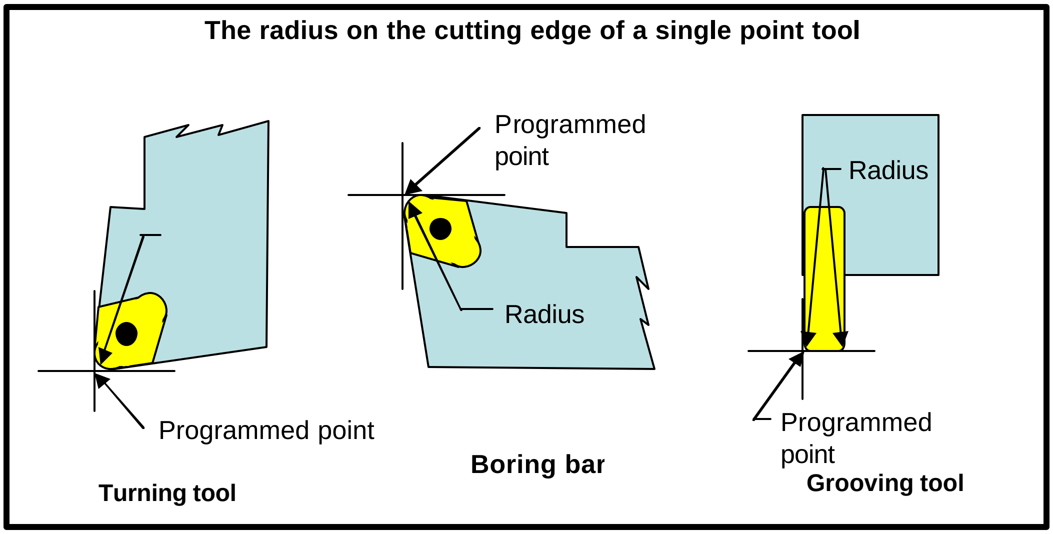
You also know that each dimension to be machined on a workpiece will have a *target value* – this is the dimension you shoot for when an adjustment must be made. Many CNC people use the mean value of the tolerance band as the target value. That is, when an adjustment must be made, they target the mean value. While there are times when this may not be appropriate (large lot sizes with small tolerances), we'll use this

***Lesson 10***

# Tool Nose Radius Compensation

*Tool nose radius compensation is only used for single point turning tools – and only when finishing surfaces that have critical shapes. While there isn't much a setup person must do with this feature (and nothing an operator must do), you should understand why it is used and be able to do your part when it is used.*

In this lesson, we discuss one other important time when you must compensate for attributes of cutting tools. It has to do with the small radius that is on the cutting edge of any single point cutting tool – like a turning tool or a boring bar. The next illustration shows this radius.




All single point tools have a small radius on the cutting edge

For cutting tools used in the United States, the actual size of the radius will be specified in inches – and there are four standard tool nose radius sizes for turning and boring inserts:

- 1/64 inch (0.0156)
- 1/32 inch (0.0316)
- 3/64 inch (0.0468)
- 1/16 inch (0.0625)

Though you may consider these radii to be quite small, this small nose radius on the edge of the cutting tool will be sufficient to cause a small deviation from the programmed shape of your workpiece – at least when angular and circular surfaces must be machined.

Remember that you are programming the extreme edges of the cutting tool in each axis. This is also illustrated above (specified as *programmed point*). Notice the small gap between the programmed point and the actual cutting edge.

This small gap will not affect the turning of diameters (parallel to the Z axis) and the machining of faces (parallel to the X axis). The next illustration shows this.

Key Concept

4

# Master The Tasks To Run A CNC Turning Center

*We have been using a building-blocks approach to present topics so far. While everything presented to this point is extremely important, things haven't been very well connected. Key Concept number four will put things together, providing you with explanations for all of the tasks you must perform when you setup and run a CNC turning center – in a very logical order.. This should provide you with what you need to begin working with CNC turning centers.*

Some of the tasks needed to setup and run a CNC turning center are *physical tasks*. That is, you'll be working with your hands to complete them. Examples include, mounting jaws on a three-jaw chuck, assembling and loading cutting tools, loading a program, and measuring workpieces. But as you learned in Key Concept number three, other tasks are *mental tasks*. They take thought to complete. While we are not saying you don't have to think when performing physical tasks, the mental tasks do not require much physical exertion. Examples include trial machining, sizing, and program modification.

Physical tasks are pretty easy to understand. When you see a person performing them, you can easily tell what they are doing. Mental tasks, on the other hand, are not so obvious – but they are every bit as important as the physical tasks. You must, of course, master all of the tasks related to setting up and running production for a CNC turning center. This will require the ability to work with your hands and think on your feet.

Key Concept number four includes two lessons:

- Lesson 11: Tasks required to setup a CNC turning center
- Lesson 12: Tasks required to complete a production run

As you know, there are some setup-related tasks that must sometimes be repeated during a production run. If for example, a cutting tool gets dull and must be replaced, the same tasks required to initially assemble it, enter offsets for it, and trial machine with it must be repeated.

Many of the tasks related to making setups and running production, of course, draw upon your basic machining practice skills. Tasks related to making workholding setups and assembling cutting tools, for example, require that you understand the related workholding- and cutting-tool-components. These tasks are identical to those that must be performed on conventional (non-CNC) machine tools. As stated many times to this point, setting up and operating a CNC turning center require a firm understanding of basic machining practices. If you have experience working with conventional machine tools, you have a head start for mastering CNC turning center setup and operation.

While Key Concept number one *introduces* basic machining practice topics you must understand, it is not nearly enough to fully master setup and operation. Additionally, you will need hands-on practice that we cannot provide in this text. At the very least, you will need the help of an experienced CNC setup people and operators when you begin working with CNC turning centers. Though this is the case, we can provide you with the principles related to setup and operation. Any aspiring setup person or operator must understand these principles before they can spend any meaningful time at the machine.

*Lesson 11*

# Tasks Required To Setup A CNC Turning Center

*We define setup time as the total time a machine is down between production runs. We define cycle time as the total time it takes to complete a production run divided by the number of good workpieces produced. If you think about it, there are only two general activities that occur on CNC turning centers – machines are either in setup or they are running production. In this lesson, we will address those things that occur while the machine is down between production runs.*

It is important to understand the distinction between making a setup and running production. The tasks you perform during setup are *getting the machine ready* to run production. Only when the setup is completed and a workpiece has passed inspection is it possible to run production. The person making the setup is called the *setup person* – the person completing the production run is called the *CNC operator* (though in many companies, one person makes the setup *and* runs production – this kind of person is commonly called a *CNC technician*).

***Setup-related tasks***

- ✍Tear down previous setup an put everything away
- ✍Gather the components needed to make the setup
- ✍Make the workholding setup
- ✍Assemble the cutting tools
- ✍Load cutting tools into the machine's turret
- ✍Assign program zero for each new tool (tool's not in the turret from the previous job)
- ✍Enter tool nose radius compensation values
- ✍Load the CNC program/s
- ✍Verify the correctness of a new or modified program
- ✍Verify the correctness of the setup
- ✍Cautiously run the first workpiece – ensure that it passes inspection
- ✍If necessary, optimize the program for better efficiency (new programs only)
- ✍If changes to the program have been made, save a corrected version of the program

In this lesson, we'll be going through this list of setup related tasks and describing each one in detail. In Lesson Twelve, we'll be doing the same for production-run-related tasks. Some of these tasks have been presented in previous lessons, and these presentations will not be repeated.

There are certain setup-related tasks that must sometimes be repeated during a production run. If for example, a cutting tool gets dull and must be replaced, the same tasks required to initially assemble it, determine its program zero assignment values, and enter its offsets must be repeated. And if trial machining is required during setup for a given tool, it will probably be required when the tool is replaced during the production run.

Many of these tasks, of course, draw upon your basic machining practice skills. Tasks related to making workholding setups and assembling cutting tools, for example, require that you understand workholding- and cutting-tool-components. And these tasks are identical to those that must be performed on conventional (not CNC) machine tools. So setting up and operating a CNC turning center require a firm understanding of basic machining practices. If you have experience working with conventional machine tools, you have a head start for mastering CNC turning center setup and operation.

This lesson is truly at the heart of the setup and operation presentations in this text. It presents the most important tasks you must understand in order to be a successful setup person or operator.

***Lesson 12***

# Tasks Required To Complete A Production Run

*Once a job is set up and the first good workpiece is efficiently machined, the rest of the workpieces must be run. Completing a production run is the job of a CNC operator – though the same person who sets up the machine is often the person who completes the production run. A misconception exists about the difficulties related to completing a production run. Many manufacturing people feel that running out a job simply requires part loading, cycle activation, and workpiece removal. In reality, there is usually a lot more to it.*

With an understanding of what it takes to set up a CNC turning center, let's turn our attention to what it takes to run the rest of the workpieces in the job. Here is a list of the related tasks:

Done during every cycle:

- Load a workpiece
- Activate the cycle
- Monitor the cycle to ensure that cutting tools are machining properly (first few workpieces only)
- Remove the workpiece
- Clean/de-burr the workpiece
- Perform specified measurements (if required)
- Report measurement results to statistical process control (SPC) system

Not required in every cycle:

- Make sizing adjustments for critical workpiece attributes
- Replace worn tools
- Remove chips from work area (if required)
- Machine maintenance

At first glance, the tasks related to completing a production run probably look pretty simple. And as long as everything is going smoothly, keeping the machine running good workpieces may be as simple as loading the workpiece, pressing the cycle start button, and removing the completed workpiece when the cycle is completed. This may be the case for the first few workpieces machined in a proven job (one run before).

It is quite common, however, that operators must make adjustments during the production run to ensure that workpiece are produced consistently. The more workpieces in the production run, the tighter the tolerances, and the more abrasive the workpiece material, the more likely it will be that adjustments must be made. The frequency of these adjustments (how often they must be made) is also related to these factors.

In this lesson, we will be taking a close look at what it takes to complete a production run once the setup is completed. As we did in Lesson Eleven, we will present the related tasks in the approximate order that a production run is completed.

Remember from Lesson Eleven that there are only two things that occur on a CNC turning center. The machine is either in setup or running production. In this lesson, of course, we will be addressing thing that occur during the production run. And this includes just about anything that happens between setups.