

## Getting Started with the Machining Center Setup and Operation Curriculum

Our course curriculums have been designed to address the needs of instructors working in three similar, but subtly different, learning environments. First, instructors working for colleges, vocational schools, technical schools, and universities will find our ready-made course curriculums especially easy to learn and implement. They make it especially easy to prepare to teach each lesson. It has been our experience that instructors teaching their first CNC courses for technical schools come from one of but two backgrounds. Either they have extensive CNC experience (possibly through working for a manufacturing company), but limited teaching experience --- or they have extensive teaching experience (teaching other courses for the school), but limited CNC experience. It is rare to find a new CNC instructor who has extensive experience in both fields. These course curriculums will help in both cases.

Our proven curriculums, structured lesson plans, audio guidance, instructor notes for each lesson, and concise lesson format will minimize the amount of work an instructor must do in preparation for teaching a new course -- and minimize the work that must be done when getting ready to teach each lesson *during* the course. The proven *key concepts* approach and fly-in text boxes make it easy for even an inexperienced instructor to stay on track during each presentation. And - the high animated slide presentations and comprehensive student manuals will make experienced instructors who may be a little weak with their CNC skills look like CNC experts!

Second, instructors working for companies having their own in-plant training will also find this curriculum easy to implement. Few companies have the resources (or the desire) to completely develop this kind of program from scratch. Additionally, success for an industrial training program is *not* a simple matter of the student getting a good grade. When finished, students *must* know how to safely program and/or operate the machine tools. Training failure will result in scrapped parts, crashed machines, and possibly even injured operators. The real-world exercises in the student workbook will prove the student's knowledge of presented materials each step of the way. When the student successfully completes this course, you can rest assured that they comprehend the subject matter.

Third, training consultants (or instructors working for technical schools) that provide custom training for manufacturing companies will find that this course curriculum makes it easy to teach CNC to their clients. Utilizing standard (and highly portable) computer equipment, the comprehensive slide show can be done on-the-road, meaning instruction can take place anywhere.

### **Five factors that contribute to learning**

While experienced instructors may find this information somewhat basic, we wish to ensure that beginning instructors understand the importance of setting up a good learning environment. Of course, the better the learning environment, the better the training program will be, and the faster, and easier it will be for students to learn. This course curriculum is well suited to facilitating the learning environment in all five ways.

*Motivation* is the most important factor in any learning environment. First and foremost, students must be highly motivated to learn. Motivation will be the driving force that makes students *stick with it* even when they are having trouble understanding information being presented during training. Indeed, *any* problem with learning can be overcome if the student's motivation is high enough. But just as important, the instructor must also be highly motivated to teach. You must have a burning desire to relate information during training in a way students can understand. When student are having problems, the instructor must be motivated enough to spend the extra time it takes to ensure that the student eventually understands presented material. This can be very challenging since students' aptitude levels vary. This course curriculum inspires motivation on both counts. The colorful and illustrative slide show, the

tutorial nature of the manual, the pertinent practice exercises, and the highly structured key concepts approach will capture and hold your students' attention, and make it easy for them to *stay* motivated. For the same reasons, instructors should find this course almost *fun to teach* - and it is easy to stay motivated with tasks you enjoy.

*Aptitude* will determine how quickly and easily learning will occur. The aptitude of the instructor for making interesting and attention-holding presentations, giving pertinent analogies, preparing illustrative visuals, designing realistic practice exercises, and in general, keeping the students interested level high will contribute to determining how quickly and easily students catch on to new material. *Instructors with high aptitude make it easy for students to learn.* In similar fashion, the students' aptitude for learning manufacturing related functions and specifically CNC also contribute to how quickly and easily learning takes place. *Students with high aptitude make it easy for the instructor to teach.* This course curriculum pays particular attention to trouble spots. From our own teaching experience, we know where students with minimal aptitude tend to have the most problems and make ample analogies to keep even the most complex topics of CNC as simple as possible to understand.

*Presentation* is the heart of training. The better the instructor prepares and delivers the presentation, the easier it will be for students to learn. Presentation can consist of many things, including the instructor's lectures, demonstrations, simulations, overhead and projector slides, videos, and anything else that helps to convey an idea. This is the strong point of our curriculums. You will find it very easy to get your ideas across with but a small amount of preparation before delivering each lesson. While you still have to talk, the slide shows, fly-in text boxes, and instructor notes will make sure you know what to say!

*Repetition* reinforces a student's understanding of learned information. Even students with extremely high aptitude will find it difficult to learn from presentations made only once. *All* training sessions should begin with a review of recent presentations. Depending upon the frequency and duration of each training session, entire sessions should, at times, should be devoted to reviewing what students should already know.

Reviews also help the instructor limit how much complex subject matter is presented during each session. Knowing that certain information will be reviewed, the instructor can avoid getting too deep into complicated topics during the first time the information is presented. Only after students have a firm grasp of basics concepts will the instructor dive deeper and introduce more complicated variations. While you may wish to do more, this curriculum includes a "Review" presentation. For each key concept, we first name the key concept and list the related lessons. We then provide a review slide for each lesson in outline format that lets you reiterate key points about each major topic in the lesson. These are simply bullet points, so you'll have to describe topics being reviewed without the benefit of graphics and animations. If students are having trouble during reviews, it should be taken as a signal that they don't truly understand the subject matter. In this case, you can easily go back to the lesson being reviewed, call up the *presentation links* slide, and click on the link that brings you to the topic in question.

*Practice with reinforcement* acts as the gauge to judge the success of training. Well designed practice exercises should be realistic, forcing the student to do things in the same way they must when training is completed. Reinforcement must come as the result of the students' practice. If the student demonstrates a firm understanding of the presented information, reinforcement should praise the success. On the other hand, if practice exposes a student's lack of understanding, reinforcement should come in the form of repeated presentations (review) and more practice, ensuring that the student eventually catches on. This course curriculum includes a comprehensive set of practice exercises as well as several quizzes in the student manual, to confirm understanding each step of the way.

### The Key Concepts approach

Most training experts agree that students learn best when they have *a light at the end of the tunnel*. The more complex the subject matter, the more important it is to tell (better yet, show) the student early in the training program just what they must master to complete the course. One important benefit of our proven key concepts approach you can do just that. With our curriculum, there are four key concepts to CNC setup and operation. Early on in the course you can truthfully say *“If you can understand just four basic ideas, you are well on your way to becoming proficient as a CNC setup person or operator.”* This gives your students a light at the end of the tunnel and makes learning CNC seem as easy as possible. Also, as you go through the course, students will know where they stand each step along the way.

Another benefit of our key concepts approach is that it lets you work at a very broad level. There are many different CNC machine and control manufacturers making this kind of equipment. Though there are many commonalities in how basic machine utilization is done among current CNC machines, no two machines will be handled exactly the same. For this reason, students will likely have to adapt to their own machines once they complete your course (especially if you teach in a technical school). In each key concept you will be stressing the broad and general reasoning behind how CNC functions, showing students *why* they must do things as importantly as *how* they do them. This reasoning can be applied to any form of CNC machine tool. Once the student understands this reasoning, *then* you will show specific techniques needed to apply the key concept to one very popular CNC control.

By the way, all of the specific examples we give in the student manual and during the slide shows are in the format for a Fanuc control. We chose Fanuc as our sample control since it is the most popular control in the industry, and since several control manufacturers (Mitsubishi Meldas, Mazatrol, Yasnac, HAAS, Fadal, and others) claim to be *Fanuc-compatible*. However, you must be prepared for the possibility that your students will be working with a control made by a manufacturer that is not Fanuc-compatible. Again, rest assured that the ten key concepts apply to every current CNC control on the market. Only the specific techniques needed to apply each key concept must change.

Yet another benefit (from an instructor’s standpoint) of the key concepts approach is that the course can end at any time once students understand the key concepts. One major problem in any training program is the limited time available for training. While manufacturing companies may have the luxury of extending a course if students are slow in picking up the material, technical schools commonly work on a very rigid time frame. If students are slow in picking up the material and getting bogged down with the details of CNC machine utilization (asking many time consuming questions), the course may end before you get through all the material. While this presents a problem even with the key concepts approach, the effects of the problem can be minimized. As long as students understand the reasoning behind each key concept, it will be just a matter of time until they figure out the details. Given our extensive and highly tutorial course manual, any student with motivation will eventually figure out the details (possibly even *after* the course ends).

One last benefit we’ll mention for the key concepts approach is that it makes reviewing the material easy. Since there are only four key concepts, they are easy to remember. You can simply restate each key concept (using the “review” slide presentation) and ask pertinent questions to confirm your students retention of material previously presented.

Key concept: Description:

- 1 Get ready to learn CNC machining centers (lessons 1-2)
- 2 Know your machine from an operator’s viewpoint (lessons 3-6)
- 3 Know the compensation types (lessons 7-10)
- 4 Master the tasks to setup and run a CNC machining center (lessons 11-12)

## **Lesson structure**

These four key concepts are divided further concise lessons. For the machining center setup and operation curriculum, there are twelve lessons. Lessons do vary in length (from about 10 minutes of presentation to about an hour), and you can find an approximate time of presentation at the end of the Lesson Plans manual.

### *Machining center setup and operation curriculum lesson structure*

- 1: Basic machining practices related to machining centers
- 2: What does a CNC machining center do?
- 3: General flow of the CNC process
- 4: Machine configurations
- 5: Buttons and switches on the operation panels
- 6: The key operation procedures
- 7: Introduction to compensation
- 8: Fixture offsets and assigning program zero
- 9: Tool length compensation
- 10: Cutter radius compensation
- 11: Tasks required to setup a CNC machining center
- 12: Tasks required to complete a production run

## **Student's Course Materials:**

All student course materials are copyrighted and must be purchased from CNC Concepts, Inc. Current pricing can be found on our website ([www.cncci.com](http://www.cncci.com)).

*Student Manuals* - These highly tutorial manuals precisely follows the slide show presentations you will be making. They are very detailed and will provide the student with an excellent way to review information you present, during the course and long after the course is finished. There is one student manual for each curriculum. Exercises are included right in the course manual. Of course, you will also want to have this manual to use as a master as you present the course.

## **Special note about answers to the exercises**

Since the student manual is a self-study manual, answers to the exercises are provided at the end of the manual (on page 273). If you do not want your students to have access to these answers as they go through your class (you want to grade them), we suggest that you ask your students to pull these pages from the manual and give them to you during your first session.

## **Instructor's Course Materials:**

***CD-rom disk including all instructor materials*** – The disks include the following instructor materials:

### ***PowerPoint Slide shows:***

Each lesson includes a slide show to provide the visuals you need to teach. They are all computer generated graphics and animations that really help you make your points during the class.

***Lesson topics links slide*** – Every lesson begins with this special slide. The lesson topics slide provides links to every main topic for the lesson. Every slide in the lesson will have a “Lesson topics” link at the bottom that returns you to this slide. Again, the lesson topics slide lists the main topic to be covered by the lesson. When you click on a topic, the presentation will skip to the slide that begins that topic. This can help in three ways. First, it provides a very interactive way to get to topics of interest (you will be clicking on topics during your presentation) as you teach. Second, you will be able to easily skip topics that you don't want to cover. Just remember that once you click on a topic, the presentation will simply continue from the slide that begins the topic. If you get into another topic (that you don't want to cover),

simply click the Lesson topics link in the lower left corner. And third, this special slide should really help when reviewing. It makes an excellent list of bullet points that you can review in a nice logical order. And of course, if students are having problems, you can easily click on the trouble-causing topic and re-present the information related to the topic. The lesson topics slide also makes a great “presentation plan”. You’ll be able to quickly introduce the main topics as you start each lesson and summarize them when your finished with the lesson.

*Fly in text boxes* – In addition to graphics and animations throughout the slide shows, we also include *fly-in text boxes* on most slides to help you understand where the presentation is going. In some cases, the *fly-in text box* will remind you to make some important point about the topic at hand. In other cases, they are included at a change of pace in the presentation, and provide the next few words of your presentation. In all cases, they will help you stay on track and minimize the amount of preparation you must do to get ready to teach.

*Review slide presentation* – A link from the startup page, this special presentation is intended to help you review material throughout the course. As stated, at least ten percent of each session should be spent reviewing information that you previously presented. This presentation is made up of at least two slides for each key concept. The first slide for each key concept shows the key concept name and the lesson/s related to the key concept. This is followed by a list of bullet points for each lesson in the key concept. Each list of bullet points is identical to the presentation links slide for the lesson. So if students are having problems during the review, you can easily call up the related lesson, go to the presentation links slide, and click on the topic of interest. Since this collection of slides makes for a very good outline for the entire course, we include a printout of the Review slide show later in this Instructor Manual.

All presentation files are easily started from the startup page, named a\_startup.ppt on the CD-rom disc.

***PowerPoint Viewer software:***

All slideshows are prepared in PowerPoint. In order to view/display/print the slide shows, you must either have the actual PowerPoint software (PowerPoint 95 or above) or the PowerPoint Viewer. We provide the PowerPoint Viewer on disk one. Since the PowerPoint Viewer does not let you modify slides, and since it requires that slide shows always start from the first slide (not very convenient when you’re trying to get to a slide in the middle of a lengthy presentation), we urge you to get the actual PowerPoint software. It can be purchased separately, and it comes with most versions of Microsoft Office.

**What you still need:**

In order to show the PowerPoint slide presentations to a group of people, you need the following items.

*A computer with Windows* - Just about any current model computer will work. If using a desktop computer, you can easily watch the monitor of the computer (facing your audience) to see the slide show while slides are displayed behind you by the projection system. Since the left mouse button advances the slides, you even have a remote slide advance button. If portability is an issue, keep in mind that all current notebooks have ample power to run the presentation software. However, be careful in your selection. Many notebooks do not allow you to send data out through the video port *and* see the slide show on the LCD screen of the notebook at the same time. Without this ability, you may have to turn around to see your slides, which can be distracting to your audience.

*A way of displaying the screen show* - You have several alternatives in this regard. All involve using a device that takes data from the video port of your personal computer. First, many schools already have a projection system that can display information from a personal computer. Basically, anything that can be shown on the computer screen can be displayed through the projection system. Second, you can use a device that sits on top of an overhead projector to display your screen shows. In essence, this device makes a transparency of what ever is on the display screen of the computer (we don’t like this kind of

device because of its brightness – it can really hurt your eyes if you try to use it as a normal overhead projector). Third, and especially if price is a concern, you can use a simple scan converter (about \$200.00 - \$300.00) and display your screen show on any television that has a *video in* connector (as most do). If you must use the RF connector of the television (where an antenna plugs in), an RF converter must be purchased. Since there are so many alternatives for displaying your slide shows, we welcome phone calls (847) 639-8847 if you have questions about your alternatives.

## Putting It All Together

### Getting Ready To Teach

As stated earlier, though these course curriculums dramatically reduce the amount of preparation you must do, they do not eliminate it completely. And as any experienced instructor will agree, the key to successful presentations is in becoming comfortable with the material you present. And the only way to get comfortable is through adequate preparation.

*Before your first course:*

**Skim the entire curriculum** - Though you do not have to be perfectly comfortable with every detail of the curriculum to begin teaching, you will at least need to understand where the course is going. You can use the course outline, lesson plans, instructor notes, and student manual to gain an appreciation for the four key concepts and the lesson structure being used.

*Before beginning each key concept:*

**Get comfortable with all lessons in the key concept** - While some key concepts have but one lesson, most have more. Be sure you feel comfortable with all major points you need to make before you begin teaching. Again, use the course outline, instructor notes, and student manual to increase your comfort level with the entire concept.

*Before you deliver a lesson:*

**Get ready to teach!** - Study the lesson plan and go through the in order to gain an understanding of key points that must be delivered during your presentation.

**Practice!** - Especially before your first few lessons, get comfortable with your equipment and the material you present by practicing your presentation. In addition to getting you ready to deliver each lesson, this should give you a rough idea of how long it will take to deliver each lesson at your own pace.

*During your presentation of each lesson:*

**Tell them what you're going to tell them** - The Lesson topics slide (first slide of every lesson will help you prepare your students for what they will be learning. While you don't have to dwell on this slide too long, it will let them see what is included in the lesson.

**Tell them** - Go through the lesson, using your slide show as a guide. Be sure to point out the page numbers and sections in the student manual where the information is also included for their own independent study. Be sure everyone is catching on. Encourage participation, questions, and comments. While you should find adequate analogies in the slide show to stress the most complex topics, you must be prepared to handle special questions and concerns. Have a blackboard or overhead available for making special points.

**Tell them what you told them** - Get back to the Lesson topics page and review the key points of the lesson. Again, encourage questions and participation. The idea is to confirm that students truly understand presented material.

*After you finish each lesson:*

**Assign and check practice exercises** - The students' responses to the practice exercises makes an excellent way to gauge your students' understanding of the subject matter. If you find that students are not doing well, it should be taken as a signal that you must review key information. If students are doing well, be sure to praise them.

*As you get deeper into the course:*

**Review often** - No student will retain every word of every presentation you make during a course as lengthy as these. On average, you should spend about 10% to 20% of your session time in review, depending upon how well your students are doing. The more problems they are having, the more time you should spend on review. One excellent way to review is to question students from the previous exercises to confirm their retention. The review slide presentation can be activated from the startup page, and will help you review all key topics.

**Let students know where they stand** - Be sure everyone knows how they are doing as they progress through the course. Assign special exercises and labs for those students having the most problems. Push those students doing well to go further.

## Answers to Exercises

### These answers are in the student manual!

Since the student manual is intended to be a self-contained self-study manual, we include answers to all the exercises at the end of the manual (page 273-279). This is fine if you would like your students to check their own work. But if you would rather not let them have access to answers (you want to check and grade their work), you must have them remove these pages from the student manual early on in the class. You can do so during your first session – before they’ve started reading the student manual – while you are introducing the class.

*This is the message just prior to the exercise answers:* If you are attending a class that uses this text, your instructor may ask you not to look at these answers prior to submitting your work. (Each exercise can be removed from this text without removing any content.) On the other hand, if you are reading this text on your own, you can use these answers to check your work.

### Exercise 1: Basic Machining Practices

- |  |   |
|--|---|
| 1) 1.00 by 3.00 by 5.00 inches (or 1 by 3 by 5 inches)             | 14) a: Yes, b: Not immediately, but it is getting close to it’s low limit – so if you said yes, you are also correct, c: deviation from target (mean) value is 0.0007   |
| 2) 1.50  | 15) a: Yes, b: No, c: deviation from target (mean) value is 0.002   |
| 3) 1.25 by 2.0 by 0.875  | 16) a: No, b: Yes, c: 0.002   |
| 4) 316 stainless steel   | 17) a: No, b: Yes, c: 0.0013  |
| 5) yes   | 18) a: Yes, b: No, c: deviation from target (mean) value is 0.003 (note that there is nothing a setup person or operator could do (without changing the program) to adjust the distance between the two holes). |
| 6) true  | 19) true  |
| 7) Plus or minus 0.001   | 20) true  |
| 8) mv: 0.75, hl: 0.751, ll: 0.749                                  |   |
| 9) mv: 0.50, hl: 0.505, ll: 0.495                                  |   |
| 10) mv: 0.8745, hl: 0.876, ll: 0.873                               |   |
| 11) true   |   |
| 12) Revision “A”   |   |
| 13) a: Yes, b: No, c: deviation from target (mean) value is 0.0003 |   |

### Exercise 2: What Does A CNC Machining Center Do?

- |                       |                               |
|-----------------------|-------------------------------|
| 1) true               | 7) b. feedrate                |
| 2) b. milling machine | 8) c. radial depth-of-cut     |
| 3) true               | 9) b. surface feet per minute |
| 4) true               | 10) true                      |
| 5) false              |                               |
| 6) a. spindle speed   |                               |

- |                        |  |
|------------------------|--|
| 11) b. center drill it | 16) true   |
| 12) d. spot drill      | 17) true   |
| 13) false              | 18) false (they recommend feedrate in per-tooth fashion) |
| 14) c. ream or bore it | 19) d. all of the above                                  |
| 15) b. tap             | 20) true   |

### Exercise 3: General Flow Of The CNC Process

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|--|---|
| 1) d. All of the above.  | the correct version of the program will be used the next time the job is run.   |
| 2) d. All of the above   |   |
| 3) One way to load a program is to actually type it using the machine's keyboard and display screen. The other is to use some form of distributive numerical control (DNC) system. | 9) true   |
| 4) The DNC system is better, since it is much faster and minimizes the effort needed to load programs.   | 10) Answers can include workholding setup documentation, a sketch or photo of the workholding setup, a cutting tool list, a list of cutting tool components, specification about where the program is stored, and a list which specifies which cutting tool is loaded into each magazine station. |
| 5) true  | 11) It would be wise to do so just in case the job does come up again – and to have a record of how the job was run in case a similar part or process must be run some day.   |
| 6) true  |   |
| 7) true  |   |
| 8) If the program is modified during the verification process, the corrected version must be sent back to the DNC system so  | 12) We cannot provide answers to this question  |

### Exercise 4: Machine Configurations

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|--|---|
| 1) true  | 7) Answers could include the spindle's speed, the spindle's rotation direction, and the spindle's power range.  |
| 2) true  |   |
| 3) true  | 8) b. M03   |
| 4) As viewed from the front of the machine, the X axis is motion left/right. The Y axis is motion fore/aft. The Z axis is motion up/down.    | 9) c. S word  |
| 5) As viewed from the front of the machine, the X axis is motion left/right. The Y axis is motion up/down. The Z axis is motion fore/aft.    | 10) d. G word   |
| 6) X plus is table motion to the left. Y plus is table movement toward the operator (front of the machine). Z plus is headstock movement up. | 11) The process breaks a rule of basic machining practice: You must rough everything before you finish anything. Since one of the holes is finish bored before the other is roughed, its position may shift (relative to the other hole) if the workpiece shifts during roughing. |

**Exercise 5:**

- 1) The machine panel which is made by the machine tool builder and the control panel which is made by the control manufacturer.
- 2) e. program
- 3) c. program check
- 4) a. position (program check also shows position displays)
- 5) b. offsets
- 6) b. the insert key
- 7) a. the input key
- 8) Answers can include: The reset button is used to clear an alarm once the problem causing the alarm is corrected. The reset button is used to bring the cursor back to the beginning of the program (in edit mode). The reset button is used to cancel the CNC cycle – this also clears the look-ahead buffer.
- 9) This mode switch position could be labeled manual or jog.
- 10) The zero return mode switch position
- 11) This mode switch position could be labeled memory or auto.
- 12) The handwheel mode switch position.
- 13) b. single block
- 14) a. dry run
- 15) the rapid override switch
- 16) the feedrate override switch
- 17) the feed hold button
- 18) the manual data input (MDI) mode switch position
- 19) false
- 20) true
- 21) We cannot provide an answer to this question.
- 22) We cannot provide an answer to this question

**Exercise 6: The Key Operation Procedures**

- 1) manual procedures, setup procedures, manual data input (MDI) procedures, program editing procedures, program operation procedures
- 2) Most machining centers require that you manually send the machine to its zero return position.
- 3) A zero return
- 4) By following the procedure to test for option G codes. Execute the G code in the MDI mode. If the machine responds with alarm number 10 (unusable G code), the machine does not have the G code.
- 5) By following the procedure to show a directory of programs.
- 6) By following the procedure to delete a program.
- 7) By following the procedure to search to a specific word in the program – in this case, a T word.
- 8) By following the procedure to modify words in a program.
- 9) Ask an experienced person to help – get them to show you the procedure and write it down so you won't have to ask again.
- 10) false
- 11) We cannot provide the answer to this question.

**Exercise 7: Introduction To Compensation**

- 1) true
- 2) false

- |  |   |
|--|---|
| <ul style="list-style-type: none"> <li>3) fixture offsets, tool length compensation, cutter radius compensation</li> <li>4) false</li> <li>5) true</li> <li>6) false</li> <li>7) b. setting the offset prior to machining in such a way that excess stock is left on a surface by a cutting tool.</li> </ul> | <ul style="list-style-type: none"> <li>8) a. H</li> <li>9) true</li> <li>10) false</li> <li>11) We cannot provide answers to this question.</li> <li>12) We cannot provide answers to this question.</li> </ul> |
|--|---|

### Exercise 8: Fixture Offsets And Assigning Program Zero

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|--|--|
| <ul style="list-style-type: none"> <li>1) false</li> <li>2) The zero return position is a reference point for, among other things, program zero assignment. It is from the zero return position that all fixture offset register values are taken. It is a very accurate location, usually at the extreme plus end of the overtravel limit for each axis.</li> <li>3) b. the distance between program zero and the zero return position must be know in each axis to assign program zero.</li> <li>4) true</li> <li>5) true</li> <li>6) For the X axis: Bring an edge finder flush with the X axis program zero surface. Retract the X axis relative position display to zero. Retract the edge finder in Z and move over in the direction of program zero by the radius of the edge finder. The center of the edge finder and spindle will be aligned with the X axis program zero surface. Reset the X axis position display again. When you send the X axis to its zero return position, the X axis position display will follow along. The X axis position display will show the X axis program zero assignment value when the machine is at its X axis zero return position. For the Y axis: Bring an edge finder flush with the Y axis program zero surface. Retract the Y axis relative position display to zero. Retract the edge finder in Z and move over in the direction of program zero by the radius of the edge finder. The center of the edge finder and spindle will be aligned with the Y axis program zero surface. Reset the Y axis</li> </ul> | <p>position display again. When you send the Y axis to its zero return position, the X axis position display will follow along. The Y axis position display will show the X axis program zero assignment value when the machine is at its Y axis zero return position.</p> <ul style="list-style-type: none"> <li>7) Send the Z axis to its zero return position. Reset the Z axis relative position display register to zero. Place a block of known height on the Z axis program zero surface. Bring the spindle face to top of the block. Add the block height to the Z axis position display value to come up with the Z axis program zero assignment value.</li> <li>8) Using a spindle-mounted dial indicator, indicate the center of the round workpiece to make the spindle center aligned with the center of the workpiece. Reset the X and Y axis relative position display values to zero. Retract the Z axis and send the X and Y axes to the zero return position. The X and Y axis position display values are the program zero assignment values in X and Y.</li> <li>9) true</li> <li>10) true</li> <li>11) false – older machines (pre-1980 or so) do not have fixture offsets.</li> <li>12) c. the machine will miss position, commonly resulting in a crash</li> <li>13) a. the machine will still move to the correct location</li> <li>14) false</li> <li>15) true</li> </ul> |
|--|--|

- 16) false
- 17) c. from the program zero point to the machine's zero return position (commonly plus)
- 18) a. from the machine's zero return position to the program zero point (commonly minus)
- 19) true
- 20) false
- 21) We'd recommend using fixture offsets for those machines that allow them.
- 22) The machine will move in the wrong direction, thinking that program zero is on the opposite side. This will usually result in an axis over-travel.
- 23) Fixture offset number one is initialized at power up.

### Exercise 9: Tool Length Compensation

- 1) true
- 2) true
- 3) false
- 4) We feel using the tool's length as the offset is better because tool length compensation values can be measured off line, tool length compensation values do not change for tools remaining in the machine from job to job, and the tool length compensation values will be correct for a tool even if it is used on a different machine.
- 5) Place a flat block on the table. Bring the spindle face to touch the block. Reset the Z axis relative position display to zero. Retract the Z axis and load a cutting tool to be measured. Bring the tool tip to the block face. The Z axis relative position display will be showing the tool length compensation value for this tool.
- 6) The machine will use the most recently instated tool length compensation value for the tool (probably the fourth tool this case).
- 7) d. the tool's length
- 8) b. the distance from the tool tip down to program zero
- 9) b. reduce the tool length compensation value by 0.005 in
- 10) a. increase it (make more positive) by 0.010 or so
- 11) b. the nose of the spindle would move to the programmed Z position (causing a crash)
- 12) false
- 13) true
- 14) false
- 15) true
- 16) false
- 17) true (assuming you want the first workpiece to be a good one)
- 18) nothing (the surface is still well within its tolerance band)
- 19) c. decrease the tool's tool length compensation offset value by 0.0003 (the surface is getting close to its low limit)
- 20) true
- 21) We cannot provide an answer to this question.
- 22) With the "common" fixture offset (fixture offset number zero) it is possible to enter the difference in gap size from one machine to another. This will allow cutting tools to be used among the various machines without having to modify the tool length compensation offset values. Fixture offsets are presented in Lesson Eight.

**Exercise 10: Cutter Radius Compensation**

- 1) true
- 2) c. and end mill
- 3) false
- 4) Answers could include: It makes calculating coordinates easier for the programmer. It allows the programmer to ignore the precise diameter of the end mill to be used. It allows a range of cutter sizes to be used. It allows sizing of surfaces machined when side milling is done. It allows the same programmed path used for finishing to be used when roughing a surface.
- 5) false
- 6) b. 0.4375 (though some machines do have cutter diameter compensation – for these machines, the value 0.875 will be placed in the cutter radius compensation offset register).
- 7) a. make it 0.001 smaller
- 8) a. increase the offset value by about 0.01 in
- 9) For machines having but one register per offset, the cutter radius compensation offset number is calculated by adding a constant value (larger than the number of tools the machine can hold) to the tool station number. For a machine that can hold 25 tools, for example, offset number 34 will be used for tool number four.
- 10) a. zero
- 11) Increase the rough milling cutter's offset by 0.03 inch. This will force the cutter to stay 0.03 away from all surfaces that are side milled.
- 12) Generally speaking, the smaller the cutter radius compensation offset, the fewer problems there will be with cutter radius compensation. Also, some companies almost always use the planned cutter size (they never use sharpened cutters which are smaller than the planned cutter size). In this case, it may be easier to place a value of zero in each cutter radius compensation offset register – especially if there isn't much need for sizing adjustments (the offset value stays zero for most milling cutters for the entire length of most jobs).

**Exercise 11: Tasks Required To Setup A CNC Machining Center**

- 1) setup
- 2) maintaining production (though workpieces must also be loaded when running the first part during setup)
- 3) maintaining production
- 4) setup
- 5) setup
- 6) setup
- 7) setup
- 8) setup
- 9) maintaining production
- 10) d. all of the above
- 11) true
- 12) true
- 13) true
- 14) false (While they can be measured on the machine, they can also be measured off line if the tool's length is used as the offset value.)
- 15) false
- 16) true
- 17) false
- 18) b. trial machining
- 19) d. all of the above
- 20) c. distance-to-go
- 21) It is normally at the plus limit of each axis. But you must ask an experienced person for confirmation.
- 22) We cannot provide an answer to this question.


**Exercise 12: Tasks Related To Completing A Production Run**

- 1) true
- 2) true
- 3) true
- 4) true
- 5) true
- 6) Offset usage should be specified in the production run documentation. Though this is the case, some companies have unwritten rules about offset usage. The tool length compensation offset number, for example is usually the same as the cutting tool's station number.
- 7) True
- 8) Remove the cutting tool and replace the cutting portion of the tool. Re-measure the cutting tool's length and if necessary, the cutting tool's radius (for milling cutters that perform side milling operations). Replace the cutting tool in the machine's automatic tool changer magazine. Enter the measured values into the appropriate offsets. If trial machining was required for the cutting tool during the initial setup, trial machining will be required during dull tool replacement.
- 9) c. reduce it by 0.0002
- 10) true
- 11) We cannot provide answers to this question.



Slides in the presentation named “review”

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# Machining Center Setup and Operation

## Course Review

[Home](#) 1

**Key Concept  
Number One** Get ready to learn about  
CNC machining centers

- 1: Basic machining practices
- 2: What does a CNC machining center do?

[Home](#) 2

### 1: Basic machining practices

- Shop safety (p. 19)
- Shop math (p. 23)
- Introduction to blueprint reading (p. 39)
- Tolerance interpretation (p. 44)
- Measuring devices (p. 50)

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### 2: What does a machining center do?

- Comparison to other machines (p. 63)
- Introduction to cutting conditions (p. 66)
- Hole machining operations (p. 69)
- Milling operations (p. 84)

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**Key Concept  
Number Two** Know the machine from an  
operator’s viewpoint

- 3: General flow of the CNC process
- 4: Machine configurations
- 5: Understanding the operation panels
- 6: Important procedures

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### 3: General flow of the CNC process

- Companies that use CNC machining centers (p. 103)
- Flow of the CNC process (p. 105)

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As you get deeper into the course, use this presentation to quickly review what you have already covered. If students are having trouble with a review topic, simply recall the presentation for the lesson, go to the presentation links slide for that lesson, and click on the topic in question to repeat the related presentation.

## Slides in the presentation named “review”

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### 4: Machine configurations

- Machine components
  - C frame style vertical (p. 111)
  - Gantry style vertical (p. 115)
  - Horizontal (p. 116)
- Directions of motion (axes)
  - C frame-style vertical (p. 112)
  - Gantry-style vertical (p. 115)
  - Horizontal (p. 116)
- Warning about polarity confusion
- Programmable functions (p. 118)
  - Spindle (p. 118)
  - Feedrate
  - Coolant (p. 120)
  - Tool changing (p. 120)
    - Double arm
    - Single arm
  - Others

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### 5: Buttons and switches

- The two operation panels (p. 127)
- Control panel buttons and switches (p. 127)
  - Keyboard
  - Display screen
- Machine panel buttons and switches (p. 132)
- Importance of the mode switch (p. 137)
  - Three basic modes of operation
    - Manual mode (p. 137)
    - Manual data input (MDI) mode (p. 138)
    - Program operation mode (p. 141)

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### 6: Key operation procedures

The importance of procedures (p. 145)

**Manual procedures:**

- To start machine and do a manual zero return
- To start the spindle
- To jog axes
- To use the handwheel
- To reset axis displays
- To enter offsets

**Program manipulation procedures**

- To edit programs

**Manual data input (MDI) procedures**

- To change tools
- To start spindle
- To do a zero return

**Setup procedures**

- To measure program zero assignment values
- To measure tool length compensation values

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### Key Concept Number Three

### The compensation types

- 7) Introduction to compensation
- 8) Fixture offsets
- 9) Tool length compensation
- 10) Cutter radius compensation

Home 10

### 7: Introduction to compensation

- Marksman analogy (p. 155)
- Analogy related to CNC compensation
- Understanding offsets (p. 159)
- Offset tables (p. 160)
  - One value per offset
  - Two values per offset
- Trial machining (p. 157)

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### 8: Fixture offsets

- Understanding program zero (p. 167)
  - Three dimensional coordinate system
  - Program zero placement
  - Program zero assignment
  - Zero return position
  - Program zero assignment values
- Assigning program zero (p. 177)
  - With fixture offsets
- Measuring program zero assignment values (p. 169)
  - In X and Y
  - In Z
  - For a round workpiece in X and Y
- Calculating program zero assignment values

Home 12

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## Slides in the presentation named “review”

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### 9: Tool length compensation

- ⌘ Reasons for tool length compensation (p. 185)
  - ⌘ Tools are different lengths
  - ⌘ Initial adjustments
  - ⌘ Tool wear
  - ⌘ Trial machining
- ⌘ Two ways to use tool length compensation (p. 186)
  - ⌘ Offset is tool length (p. 187)
    - ⌘ Measuring on machine
    - ⌘ Measuring off line
  - ⌘ Offset is tool tip to work surface (p. 190)
- ⌘ Sizing and trial machining (p. 195)

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### 10: Cutter radius compensation

- ⌘ Reasons for cutter radius compensation (p. 205)
  - ⌘ When cutter radius compensation is used
  - ⌘ Simplifies calculations
  - ⌘ Range of cutter sizes
  - ⌘ Sizing & trial machining
- ⌘ Two ways to use (p. 211)
  - ⌘ Offset is cutter radius
  - ⌘ Offset is deviation
- ⌘ Determining which offset is used
- ⌘ Sizing and trial machining (p. 212)
  - ⌘ Sizing
  - ⌘ Trial machining

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Key Concept  
Number Four

### Master the tasks required to setup and run a CNC machining center

- ⌘ 11 – Tasks required for setup
- ⌘ 12 – Tasks required to complete a production run

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### 11: Task required for setup

- ⌘ CNC personnel responsibilities
- ⌘ Setup tasks versus production-maintaining tasks
- ⌘ Tasks related to setup (p. 221)
  - ⌘ Tear down previous setup
  - ⌘ Clean machine
  - ⌘ Make new workholding setup
  - ⌘ Assign program zero/s
  - ⌘ Assemble cutting tools
  - ⌘ Load cutting tools
  - ⌘ Measure cutting tools
  - ⌘ Enter offsets for cutting tools
  - ⌘ Load CNC program
  - ⌘ Verify program (p. 236)
  - ⌘ Re-save corrected program

Illustrations from manual:

- Example job
- Setup sheet
- Tool drawing
- Program verification example job
- Program listing for example job

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### 12: Tasks to complete a production run

- ⌘ Tasks related to completing a production run (p. 259)
  - ⌘ Production run documentation
  - ⌘ Load workpiece
  - ⌘ Activate & monitor cycle
  - ⌘ Maintain critical dimensions (with offsets)
  - ⌘ Replace worn tools
  - ⌘ Unload workpiece
  - ⌘ Cleaning & deburring workpiece
  - ⌘ Inspection & SPC reporting
  - ⌘ Preventive maintenance

Illustrations from manual:

- ⌘ Production run documentation

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