Trade of Toolmaking

Module 6:	Introduction to CNC
Unit 1:	CNC Machine Tools
	Phase 2

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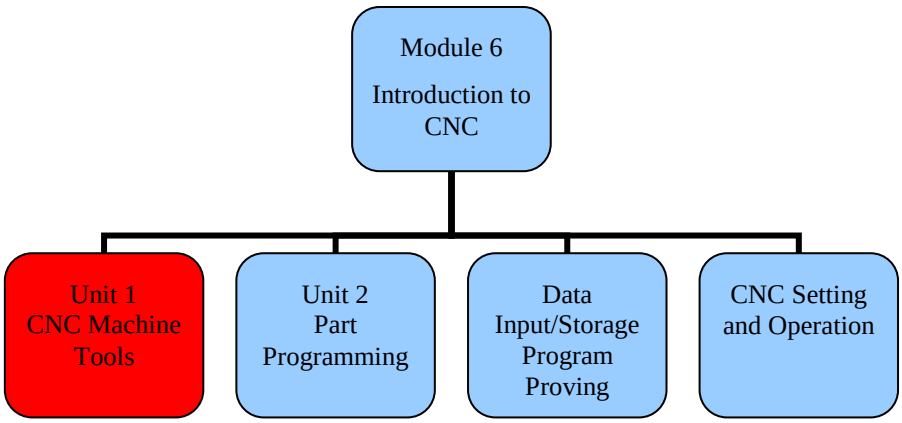
Unit Objective

On completion of this unit you will be able to explain the differences between a CNC machine and a conventional machine and also explain what CNC means.

Introduction

Module six of this course covers CNC machining. This is the first unit in module six and introduces the basics of the CNC machine. The CNC machine is now used widely throughout industry both in the production environment and in the Toolroom. On the conventional machine the operator machines the workpiece to the drawing, where the accuracy of the final machined part depends on the skill of the operator. The operator is also responsible for tasks such as starting and stopping the machine, turning the coolant on and off, changing the tool, and changing the spindle speed and cutter feed rate. When programmed correctly, the CNC machine will perform all these tasks and consistently machine multiple parts to a high degree of accuracy. Production time can also be reduced due the fact that the tool can be feed at a rapid feed rate to the work. Also complex form tools are not required as the CNC machine can generate the required profile.



By the end of this unit you will be able to:

- Define the meaning of computer numerical control.
- List and compare the constructional details which distinguish a CNC machine tool from a conventional machine tool.
- List and describe the advantages of CNC machines compared to conventional machines.

1.0 The Meaning Of Computer Numerical Control

Key Learning Points

Definition the meaning of computer numerical control.

1.1 Definition The Meaning Of Computer Numerical Control

The computer numerical control (CNC) machine has a built-in computer, which is used to store and send instructions to different parts of the machine in the form of code. The machine responds to this coded information in a precise and ordered manner to carry out various machining functions. Instructions are supplied to the machine as a series of blocks of information. A block of information is a group of commands sufficient to enable the machine to carry out one individual machining operation e.g. move the cutter form position 1 to position 2 at a specified feed rate.

2.0 The Differences Between CNC Machines Tools And Conventional Machine Tools

Key Learning Points

Machine axis determination for horizontal and vertical spindle machines. Constructional details e.g. special configurations to increase accuracy. Recirculating ball leadscrews and anti-friction slideways. Use of servo and stepping motors in slide movement. Visual displays unit – user interfaces. Swarf removal systems.

2.1 Machine Axis Determination For Horizontal And Vertical Spindle Machines

The primary axes of a machine are designated as X, Y, Z, which have positive and negative values. The Z-axis is always the main spindle axis and is positive away from the work, which is for safety reasons. The X-axis is always horizontal and parallel to the surface of the work. The Y-axis is perpendicular to both X and Z axes.

For the milling machine, the Z + direction is upwards away from the work, Z – direction is downwards into the work. The X + direction is to the right of the work and the X – direction to the left. The Y + direction is back into the machine and the Y- direction is directly towards the operator.

For the lathe, the Z + direction is to the right and away from the work, Z – direction is to the left and into the work. The X + direction is directly towards the operator, the X – direction is back into the machine away from the operator.

Ref: Timings, R.L. 1998, *Manufacturing technology*, vol. 1, 3rd edn, Pearson Education Limited, chapter 5, *Numerical control part programming*, sec. 5.4, *Axis nomenclature*, p. 176.
ISBN-13: 9780582356931

2.2 Constructional Details E.G. Special Configurations To Increase Accuracy

The conventional machine is designed to have an operator standing directly in front controlling the machine. For the CNC machine this is no longer required as the machine is operating under program control.

CNC machines have more rigid construction when compared to the conventional machine. The slide ways, guide and spindles of the CNC machine all look over proportioned when compared to the conventional machine. The structure of the CNC machine is therefore designed to cope with the torsional forces and heavy duty cutting imposed on these machines.

Ref: Timings, R.L. 1998, *Manufacturing technology*, vol. 1, 3rd edn, Pearson Education Limited, chapter 5, *Numerical control part programming*, sec. 53, *Advantages and limitations*, p. 173.
ISBN-13: 9780582356931

2.3 Recirculating Ball Leadscrews And Anti-Friction Slideways

The *slideways* on a conventional machine operate under the conditions of sliding friction, where the friction is higher at lower velocities, which can result in jerky slide movements. To overcome this rolling friction can be used instead of sliding friction, where re-circulating roller bearings are positioned under the slideways. The *leadscrews* in conventional machines are usually of the Acme thread form, which are inefficient due to the high frictional resistance

between the flanks of the screw and the nut. There is also backlash, because of the clearance between the screw and the nut. This has been replaced in the CNC machine with the re-circulating ball lead screw, where both the leadscrew and the nut have a precision ground radiused shaped thread. The space or track between the leadscrew and nut is filled with an endless stream or ball bearings. The advantages are longer life, less frictional resistance, lower torque required, more precise positioning of slides, where backlash is almost completely eliminated.

Ref: Timings, R.L. 1998, *Manufacturing technology*, vol. 1, 3rd edn, Pearson Education Limited, chapter 4, *Kinematics of manufacturing equipment*, sec. 4.5, 4.6, p. 153.
ISBN-13: 9780582356931

2.4 Use Of Servo And Stepping Motors In Slide Movement

The slides and spindle of the CNC machine are driven by either stepper motor, which are used in an open-loop system or servo motors, which are used in a closed-loop system. *Stepper motor* – a digital signal is sent from the controller to the motor in the form of pulses, which will cause the motor to rotate through a specified angle, which causes the slide to move by the required distance, e.g. if five digital pulses are sent to the stepper motor then it will rotate by five steps, which is converted to linear movement by the leadscrew. The speed by which the pulses are sent to the stepper motor will determine the velocity of the slide movement. As the distance moved by the slide and the feed can be accurately controlled by the CNC control system, then there is no need for positional or velocity feedback. There are however some disadvantages associated with this open-loop system using stepper motors:

- If the machine axis is stalled through overload, the pulses will continue to count and loss of position will occur.
- The maximum output of power from a stepper motor is relatively low.
- The pulse rate or frequency is limited therefore the maximum axis feed rate is restricted, which means that the rapid traverse speeds are low.

The stepper motors are only used on small low powered machines.

Servo Motor – the servo motor requires both positional and velocity feedback, which means that the actual position and velocity of the slideway is continuously compared to the digital signal that is being sent out by the controller. This therefore is a closed-loop system. The device used to provide feedback from the slide to the controller is a transducer, which converts mechanical displacement into an electrical signal.

Ref: Timings, R.L. 1998, *Manufacturing technology*, vol. 1, 3rd edn, Pearson Education Limited, chapter 5, *Numerical control part programming*, sec. 5.5, *Control systems*, p. 177.
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2.5 Visual Displays Unit – User Interfaces. Swarf Removal Systems

The visual display unit (VDU), which is also called a monitor or a display is normally built-in to the side panel of the CNC machine. It visually lists the machining program in the form of G-codes and can also be used to show a graphical display of the path that the cutting tool will take to machine the part. A keyboard close to the VDU allows programs to be written directly into the controller unit of the machine or can be used to modify existing programs. It is more common nowadays to prepare the program on a separate computer and then load it onto the CNC machine later. The advantage of this is that the CNC machine is not idle while the program is being written.

2.6 Swarf Removal Systems

When swarf builds up on the table of a conventional machine, it is usually removed by the machine operator. The build up is easily seen by the operator and removed when required. However for CNC machines swarf build-up is a problem due to the high rates of metal removal and the fact that CNC machines may not have an operator present during machining. Therefore in CNC machines have built in swarf removal equipment such as rotary screw or linear conveyors. Slanted beds in CNC lathes allow swarf to fall away into the base of the machine. Multiple coolant nozzles around the cutting zone can assist in removing swarf.

3.0 Advantages Of CNC Machines When Compared To Conventional Machines

Key Learning Points

Advantages of CNC machining: high accuracy and repeatability, production times, safety. Elimination of special jigs and fixtures. Reduction of machine set up times. Flexibility in changes of component design. Reduction of operation error. Complex one-off components and small batch quantities. Guarding arrangements for CNC machines. Adaptability and advantages of CNC within modern and evolving industries including the apprentices workplace.

3.1 Advantages Of Cnc Machining: High Accuracy And Repeatability, Production Times, Safety

Once the program has been written and proved, parts can be consistently machined to a high degree of accuracy and consistency. Production time can also be reduced due the fact that the tool can be feed at a rapid feed rate to the work. Also complex form tools are not required as the CNC machine can generate the required profile. Safety has also been improved as most CNC machines have safety features such as guards.

Ref: Timings, R.L. 1998, *Manufacturing technology*, vol. 1, 3rd edn, Pearson Education Limited, chapter 5, *Numerical control part programming*, sec. 5.3, *Advantages and limitations*, p. 173.
ISBN-13: 9780582356931

3.2 Elimination Of Special Jigs And Fixtures

Production time can also be reduced and costs reduced due the fact that writing a part program is quicker and cheaper than manufacturing jigs and fixtures.

3.3 Reduction Of Machine Set Up Times

Setup times can be reduced when compared to the setup times on conventional machines due to the fact that equipment such as, the rotary table, jigs, fixtures, form tools etc., do not need to setup.

3.4 Flexibility In Changes Of Component Design

When the program is written to the drawing dimensions, a trial part is machined to prove the program. The machined part is rarely correct on the first run, therefore modifications will need to be made to the program to bring some features within the required tolerance band. This is easily done by calling up the program, which will be displayed on the screen. The operator then scrolls down to the line where the value needs to be changed. When the change is made the program can be run again. Also future design changes can be made in the same way.

3.5 Reduction Of Operation Error

Provided that the program is correct and the cutting tools are setup properly no errors will occur in the work. As explained above, the program is normally proved in advance of production. Operator fatigue, boredom or inattention will not affect the quality or the duration of machine as can occur when machining on a conventional machine.

3.6 Complex One-Off Components And Small Batch Quantities

CNC machines are ideal for one-off components and small batch quantities. The fast change-over times that can be achieved by the CNC machine means that small batches can be machined economically. The program needs to be prepared on a separate computer so that the CNC machine can remain in production. The program can be stored on the CNC machine and called up when required again in the future.

3.7 Guarding Arrangements For Cnc Machines

Safety has also been improved when compared to conventional machines, as most CNC machines have safety features such as guards. The machine is only accessible through the sliding doors that are closed prior to the machine starting up. Safety switches are placed behind the sliding doors will not allow the machine program to run until the doors are closed. Also, if the doors are opened the machine will switch off.

3.8 Adaptability And Advantages Of CNC Within Modern And Evolving Industries Including The Apprentices Workplace

In the past it was adequate for the apprentice Toolmaker to be trained on conventional milling machines and the lathes. In order to use these machines effectively the apprentice had to learn to use other equipment such as the sine bar, rotary table, dividing head etc., on the milling machine and learn how to turn tapers, stepped diameters, threads etc., on the lathe. Nowadays the CNC machine is used through out industry. It can perform all the above tasks and can also be programmed and run by semi-skilled operators. It is still very important to be proficient in all aspects of the conventional milling machine and lathe, but learning to use the CNC machine is a necessary requirement of the modern day apprentice.

Summary

The meaning of computer numerical control: The computer numerical control (CNC) machine has a built-in computer, which is used to store and sent instructions to different parts of the machine in the form of code. The machine responds to this coded information in a precise and ordered manner to carry out various machining functions. Instructions are supplied to the machine as a series of blocks of information. A block of information is a group of commands sufficient to enable the machine to carry out one individual machining operation e.g. move the cutter form position 1 to position 2 at a specified feed rate.

The differences between CNC machines tools and conventional machine tools: The conventional machine is designed to have an operator standing directly in front controlling the machine. For the CNC machine this is no longer required as the machine is operating under program control.

CNC machines have more rigid construction when compared to the conventional machine. The slide ways, guide and spindles of the CNC machine all look over proportioned when compared to the conventional machine. The structure of the CNC machine is therefore designed to cope with the torsional forces and heavy duty cutting imposed on these machines. The quality of parts produced from a CNC machine is more consistent.

The slides and spindle of the CNC machine are driven by either stepper motor, which are used in an open-loop system or servo motors, which are used in a closed-loop system. The stepper motors are only used on small low powered machines.

Advantages of CNC machines when compared to conventional machines: Once the program has been written and proved, parts can be consistently machined to a high degree of accuracy and consistency. Production time can also be reduced due the fact that the tool can be feed at a rapid feed rate to the work. Also complex form tools are not required as the CNC machine can generate the required profile. Safety has also been improved as most CNC machines have safety features such as guards.

Suggested Exercises

1. Draw a free hand isometric sketch of a CNC milling machine and label the primary axes of the machine, showing its positive and negative values.
2. Draw a free hand isometric sketch of a CNC lathe and label the primary axes of the machine, showing its positive and negative values
3. Sketch the anti-friction slideways and re-circulating ball lead screw used in CNC machines and explain the advantages of these features over those used in conventional machines.
4. Sketch a block diagram of an open-looped system and a closed-loop system and explain which type is used for each system.
5. List the advantages of producing parts on a CNC machine compared to a conventional machine.

Questions

1. What is the meaning of CNC?
2. What is the difference between the Slideways on conventional machine compared to those of a CNC machine?
3. How is swarf removed on high production CNC machines?
4. How are the tables and spindle driven on a CNC machine?
5. Explain the difference between the open-loop system and the closed-loop system?

Answers

1. CNC means Computer Numerical Control.
2. The slideways on a conventional machine operate under the conditions of sliding friction, where the friction is higher at lower velocities, which can result in jerky slide movements. To overcome this rolling friction can be used instead of sliding friction, where re-circulating roller bearings are positioned under the slideways.
3. Some CNC machines have built in swarf removal equipment such as rotary screw or linear conveyors. Slanted beds in CNC lathes allow swarf to fall away into the base of the machine.
4. The slides and spindle of the CNC machine are driven by either stepper motors or servo motors.
5. With the open loop system a digital signal is sent from the controller to the Stepper Motor, which causes the slide to move by the required distance. There is no feed back, therefore there is no means of comparing the final position to the position in which it was commanded to go.
   In the closed-loop system a digital signal is sent from the controller to the Servo Motor, which causes the slide to move by the required distance. The actual position and velocity of the slideway is continuously compared to the digital signal that is being sent out by the controller.

Recommended Additional Resources

Reference Books

Black, Bruce J 2004, *Workshop processes, practices and materials*, 3rd edn, Elsevier Science & Technology.

ISBN-13: 9780750660730

Timings, R.L. 1998, *Manufacturing technology*, vol. 1, 3rd edn, Pearson Education Limited.

ISBN-13: 9780582356931