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DEUTSCHE ZUSAMMENARBEIT
Norwegian Embassy
Islamabad

DIES AND MOULDS MAKER


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LEARNER GUIDE

National Vocational Certificate Level 3

Version 1 - August, 2019

NAVTTC

Implemented by
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Published by
National Vocational and Technical Training Commission
Government of Pakistan

Headquarter
Plot 38, Kirthar Road, Sector H-9/4, Islamabad, Pakistan
www.navttc.org

Responsible
Director General Skills Standard and Curricula, National Vocational and Technical Training Commission
National Deputy Head, TVET Sector Support Programme, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Layout & design
SAP Communications

Photo Credits
TVET Sector Support Programme

This document has been produced with the technical assistance of the TVET Sector Support Programme, which is funded by the European Union, the Federal Republic of Germany and the Royal Norwegian Embassy and has been commissioned by the German Federal Ministry for Economic Cooperation and Development (BMZ). The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH in close collaboration with the National Vocational and Technical Training Commission (NAVTTC) as well as provincial Technical Education and Vocational Training Authorities (TEVTAs), Punjab Vocational Training Council (PVTC), Qualification Awarding Bodies (QABs)s and private sector organizations.

Document Version
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Introduction

Welcome to your Learner's Guide for the *Dies and mould maker level 3*. It will help you complete the training and go on with further study or go straight into employment.

The *Dies and molds maker level 3 training* is to engage young people with a program of development that will provide them with the knowledge, skills and understanding to start their career in Pakistan. This qualification will not only build the capacity of existing workers of manufacturing engineering sector but also support the youth to acquire skills best fit in manufacturing industry.

The main elements of your learner's guide are:

- **Introduction:**
    - This includes a brief description of your guide and guidelines for you to use it effectively
- **Modules:**
    - The modules form the sections in your learner's guide
- **Learning Units:**
    - Learning Units are the main sections within each module
- **Learning outcomes**:
    - Learning outcomes of each learning units are taken from the curriculum document
- **Learning Elements:**
    - This is the main content of your learner's guide with detail of the knowledge and skills (practical activities, projects, assignments, practices etc.) you will require to achieve learning outcomes stated in the curriculum
    - This section will include examples, photographs and illustrations relating to each learning outcome
- **Summary of modules**:
    - This contains the summary of the modules that make up your learner's guide
- **Frequently asked questions**:
    - These have been added to provide further explanation and clarity on some of the difficult concepts and areas. This further helps you in preparing for your assessment.
- **Multiple choice questions for self-test**:
    - These are provided as an exercise at the end of your learner's guide to help you in preparing for your assessment.

Frequently Asked Questions

1. What is Competency Based Training (CBT) and how is it different from currently offered trainings in institutes?	Competency-based training (CBT) is an approach to vocational education and training that places emphasis on what a person can do in the workplace as a result of completing a program of training. Compared to conventional programs, the competency based training is not primarily content based; it rather focuses on the competence requirement of the envisaged job role. The whole qualification refers to certain industry standard criterion and is modularized in nature rather than being course oriented.
2. What is the passing criterion for CBT certificate?	You shall be required to be declared “Competent” in the summative assessment to attain the certificate.
3. How can I progress in my educational career after attaining this certificate?	You shall be eligible to take admission in the National Vocational Certificate Level-4 in Dies and mould maker and take admission in a level-5, DAE or equivalent course. In certain case, you may be required to attain an equivalence certificate from The Inter Board Committee of Chairmen (IBCC).
4. What is the importance of this certificate in National and International job market?	This certificate is based on the nationally standardized and notified competency standards by National Vocational and Technical Training Commission (NAVTTC). These standards are also recognized worldwide as all the standards are coded using international methodology and are accessible to the employers worldwide through NAVTTC website.
5. Which jobs can I get after attaining this certificate? Are there job for this certificate in public sector as well?	You shall be able to take up jobs in the manufacturing and dies and mould making Industries as a mould maker for the production of plastic parts, sheet metal parts and house hold goods.
6. What are possible career progressions in industry after attaining this certificate?	You shall be able to progress up to the level of shop supervisor after attaining sufficient experience, knowledge and skills during the job. Attaining additional relevant qualifications may aid your career advancement to even higher levels.
7. Is this certificate recognized by any competent authority	This certificate is based on the nationally standardized and notified

in Pakistan?	competency standards by National Vocational and Technical Training Commission (NAVTTC). The official certificates shall be awarded by the relevant certificate awarding body.
8. Is on-the-job training mandatory for this certificate? If yes, what is the duration of on-the-job training?	On-the-job training is not a requirement for final / summative assessment of this certificate. However, taking up on-the-job training after or during the course work may add your chances to get a job afterwards.
9. What is the examination / assessment system in this program?	Competency based assessments are organized by training institutes during the course which serve the purpose of assessing the progress and preparedness of each student. Final / summative assessments are organized by the relevant qualification awarding bodies at the end of the certificate program. You shall be required to be declared "Competent" in the summative assessment to attain the certificate.
10. Does this certificate enable me to work as freelancer?	You can start your small business as a Dies and mould maker. You may need additional skills on entrepreneurship to support your initiative.

DIES AND MOULDS MAKER

Module-1

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Modules

Module 1: Ensure Health, Hygiene and Safety of Other Individuals at Work

Objective of the module:

Duration: 30 Hrs **Theory:** Hrs **Practical:** Hrs

Learning Unit	Learning Outcomes	Learning Elements	Materials Required

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Module-2

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Module 2: 071500970 Perform Electric Discharge Machine (EDM) Operations

Objective of the module: This module describe the performance out comes, skills and knowledge required to perform electric discharge machine .It covers job setting up, running EDM related simulation and producing cavities from the machine.

Duration: 100 Hrs **Theory:** 10 Hrs **Practical:** 90 Hrs

Learning Unit	Learning Outcomes	Learning Elements	Materials Required
LU1: **Set electrode**	**The trainee will be able to:** Perform inspection of electrode before mounting Mount electrode on spindle according to standard procedure Dial electrodes as per standard procedure	Working principle and applications of EDM Inspection of electrode size with respect to roughing and finishing Electrode materials i.e. copper, graphite, steel Electrode mounting tools i.e. electrode holder, collect, oscillating head. Knowledge of dialing devices i.e. dial indicator, lever gauge, magnetic stand, c clamp for lever gauge etc. Major functional parts of an EDM. **Parts:** control panel, head, machine bed, di-electric fluid tank, working axis.	EDM Copper electrode Electrode holder Collet set Oscillating head Dial indicator with magnetic stand C-clamp with lever gauge
LU2: **Set workpiece**	**The trainee will be able to:** Clamp work piece according to job specification Dial the work piece as per standard procedure	Work holding devices for EDM i.e. magnetic table, grinding vice, concentric chuck, laminated blocks etc. Method of dialing work piece Method of aligning electrode with work piece. Use of orbicut attachments	MS plate Laminated blocks Grinding vice Three jaws & four jaws chuck

	Align the electrode according to workpiece as per drawing**.**		
LU3: **Set machine parameters**	**The trainee will be able to:** Set electrode height & depth reference to workpiece Set on time & off time Set machine ampere according to surface finish	Knowledge of machine parameters and its effects. **Parameter:** Amperage, voltage, on time, off time, electrode height, pulse time, flushing Knowledge of grades of surface textures (VDI scale)	EDM
LU4: **Set flushing**	**The trainee will be able to:** Check & maintain fluid level in the storage tank Set the nozzles as per job specifications Set the control of dielectric flow Set the nozzles Set external / internal flushing method as per specification	Importance of maintaining fluid level in the storage tank and Purpose of flushing Methods of flushing i.e. injection, suction, through nozzle, through electrode, die electric fluid height limit in tank etc. Method of setting flushing (external / internal)	EDM Die-electric fluid Flushing nozzles Magnetic stand Electrode with internal flushing supplement

LU5: **Carry out machining operation**	**The trainee will be able to:** Set machine parameters according to the required surface finish Set the pulsation time according to the flushing Carry out machining process as per standard procedure Ensure proper monitoring.	Knowledge of grades of surface finish on EDM (use of VDI scale) EDM operating techniques / tips Importance of pulsation time. Safe operating procedure for EDM	EDM MS plate Copper electrode VDI scale
LU6: **Carry out final inspection**	**The trainee will be able to:** Prepare the work piece for inspection Visually Inspect the work piece Manage the required measuring tools Perform the required inspection as per drawing Follow relevant health & safety procedures	Knowledge of inspection tools. **Tools:** Vernier caliper, micrometer, dial indicator, lever gauge, VDI scale. Knowledge of inspection method i.e. measurement techniques, sampling techniques	Vernier caliper Micrometer Dial indicator Lever gauge VDI scale

LU7: **Demonstrate safe working practice and housekeeping**	**The trainee will be able to:** Select & use appropriate PPEs. Maintain cleanliness at the workplace Ensure relevant safety procedure for EDM operation Ensure fire safety is available around the workplace Ensure proper ventilation at the workplace.	Hazards associated with EDM shop Health and safety relevant to EDM shop Knowledge of classes of fire. i.e. A, B, C and D class. Advantages of good ventilation in an EDM room.	PPEs for EDM

Examples and illustrations

Working principle and applications of EDM

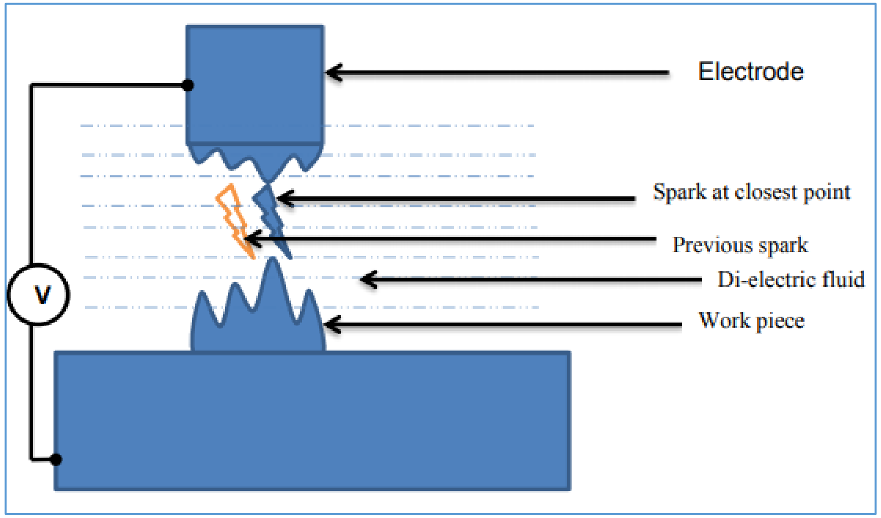
For more details please visit: https://www.automationmag.com/images/stories/LWTech-files/91%20Electrical%20Discharge.pdf

Introduction

EDM is a non-conventional machining technique uniquely used for cutting metals which are not possible to cut with traditional methods. EDM only works with materials which are electrically conductive. Delicate cavities and intricate contours which are difficult to produce with a grinder or other machines can be done with **Electrical Discharge Machining** or EDM.

Working Principle:

EDM is a thermal process i.e. material is removed by heat. When electrode is brought closer to the work piece, sunk in the dielectric fluid, current is passed to the electrode and the work piece, which generates heat in the form of frequent series of sparks that vaporizes the pieces at the closest point of work piece and electrode. After removing the piece at the closest distance between electrode and work piece, the next spark occurs simultaneously at the next closest point between them and so on. This process results on forming a cavity on the work piece with the shape of the electrode. That is how the end result is obtained as required. Since the job is done by the series of electric sparks, the electrode and work piece must be electrically conductive. This is also the limitation of the Electrical discharge machining process. It does not work with non-conductors.



During the electric discharge process, the electrode is not supposed to touch the work piece; instead it must be at the closest distance to successfully produce the spark. This distance is called the “sparking gap”. [4] If the electrode touches the work piece, there will not be a spark or material vaporization, which is the main idea of this process. The dielectric fluid is required to maintain the sparking gap between the electrode and the work piece

Applications of EDM

For more details please visit: http://mechanicalinventions.blogspot.com/2016/01/electrical-discharge-machining-edm.html

Generally EDM is hugely used for machining burr free intricate shapes as well as narrow slots and blind cavities. Sinking of dies, plastic molding, die casting compacting, cold heading, extrusion, press tools, wire drawings are some of the examples of its application. Negative tool geometry can also be generated on a w/p if suitable tool can be made. EDM is very useful for machining small holes. It is also used to cut slot in diesel fuel injection nozzles. It is also used in air craft engines and brake valves etc.

Electrode size with respect to roughing and finishing

The cavity on the work piece is always larger than the size of the electrode. This excess cut is called “overcut” or “over burn”. The main reason for overcut is the amount of electrical current. Overcut is always measured per side. It can range from 0.20 mm to 0.63 mm which is huge. Higher amperage results in the larger overcut. Overcut entirely depends upon material and the power setting, therefore, it remains constant in every use, and hence, variation of 0.0025 mm can be achieved in conventional EDM. This increases the machining time and hence increases the cost.

Electrode materials

For more details please visit: https://www.firstratemold.com/select-a-suitable-electrode-material-for-edm/

Electrode material should be such that it would not undergo much tool wear when it is impinged by positive ions. Thus the localized temperature rise has to be less by tailoring or properly choosing its properties or even when temperature increases, there would be less melting. Further, the tool should be easily workable as intricate shaped geometric features are machined in EDM. Thus the basic characteristics of electrode materials are:

- High electrical conductivity – electrons are cold emitted more easily and there is less bulk electrical heating
- High thermal conductivity – for the same heat load, the local temperature rise would be less due to faster heat conducted to the bulk of the tool and thus less tool wear
- Higher density – for the same heat load and same tool wear by weight there would be less volume removal or tool wear and thus less dimensional loss or inaccuracy
- High melting point – high melting point leads to less tool wear due to less tool material melting for the same heat load
- Easy manufacturability
- Cost – cheap

The followings are the different electrode materials which are used commonly in the industry:

- Graphite
- Electrolytic oxygen free copper
- Tellurium copper – 99% Cu + 0.5% tellurium
- Brass

Electrode mounting

Broadly, the EDM process employs an electrode which is brought into contact with a workpiece to form a cavity in the workpiece. The electrode is machined to provide a desired shape, corresponding to the final desired shape of the cavity. The EDM process is typically employed to manufacture tools and dies.

In the EDM process, setting up of the EDM electrode on the EDM machine is a critical step. The electrode must be properly positioned in the horizontal X and Y axes, as well as in the vertical Z axis. The electrode is typically mounted to an electrode holder, which includes a stem adapted to be received within a hydraulic quick clamp holder, which is then mounted to a chuck or the like. The electrode must be carefully positioned relative to the electrode holder, to ensure that the electrode is properly positioned relative to the EDM machine. In the past, this has been a time-consuming and difficult step in the setting-up process.

Various ways of mounting the electrode to the electrode holder are known. For instance, the electrode can be soldered to a flat end of the electrode holder, or the electrode may be provided with a recess adapted to receive the end of the holder, with the electrode being glued in place on the holder. Alternatively, a threaded opening can be formed in the electrode to receive a male threaded projection provided on the electrode holder, or horizontal passages formed in the electrode, through which threaded fasteners extend to fix the electrode to the electrode holder. One such arrangement provides a vertical flat surface against which a flat inner surface of the electrode is engaged, with bolts extending through the electrode and into threaded openings formed in the vertical flat surface of the electrode holder. While the last-described mounting arrangement provides positioning of the flat surface of the electrode in one horizontal direction, there is nothing in the prior art which discloses any means for positioning the electrode in the other horizontal direction when the electrode is being mounted to the electrode holder.

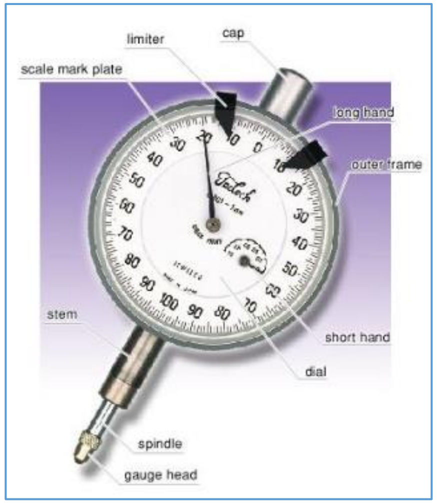
Knowledge of dialing devices

For more details please visit: https://hotrodenginetech.com/how-to-use-a-dial-indicator/

And http://www.niigataseiki.net/official/english/manual/pdf/15167679.pdf and also visit http://www.alignmentknowledge.com/dial-indicator-alignment-basics/

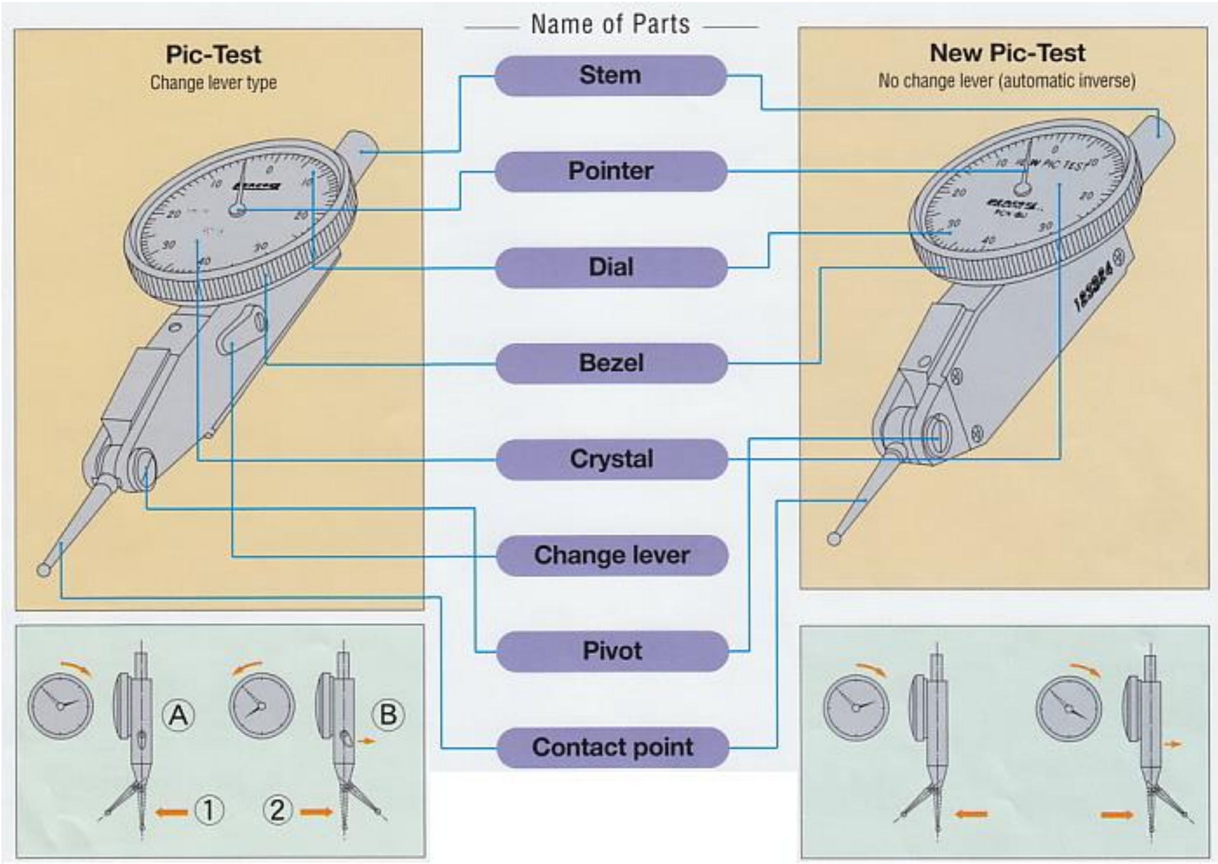
Dial Indicators:

Dial indicators are important devices used in manufacturing and metal engineering among others. These devices measure small linear distances that are important in the establishment of precision and accuracy.



Lever type dial indicator / lever gauge:

Lever Dial Indicator are characterized by their lever and scroll mechanisms, which cause the stylus to move. This type of dial indicators are more compact and easier to use than plunger-type dial indicators and are therefore quite often used.



Magnetic stands:

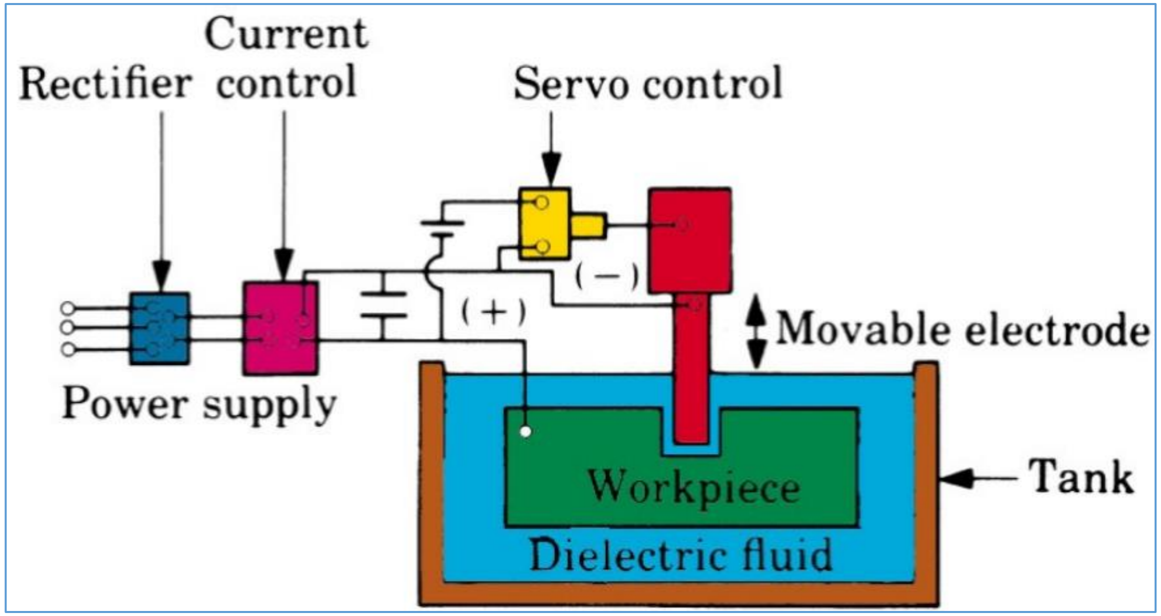
Accurate use of a dial indicator requires rigid mounting and absolute stability. If the indicator moves all while the measurement is being taken, the measurement is compromised. Hence dial indicators are almost always used with an adjustable magnetic base that can be clamped firmly to a nearby surface. The magnetic base can be adjusted to position the dial indicator so that the stem can read movement in the same direction as the part being measured.

Major functional parts of an EDM.

For more details please visit: https://www.engineering.com/AdvancedManufacturing/ArticleID/10100/EDM-101-Electrical-Discharge-Machining-Basics.aspx

An EDM machine has following major aspects.

- Controlled axis
- Electrical generator
- Control panel
- Work table
- Dielectric fluid container



An electrode is attached to the controlled axis that moves up and down according to need. Its movement is controlled with the help of a control panel. The control panel also controls the amount of electricity supplied to the electrode and the work piece. The work table is inside the di-electric fluid container and holds the work piece in place. The di-electric fluid container, as name applies, contains the di-electric fluid. Both electrode and work piece are submerged in the fluid container for the process. The electrical generator is plugged in the power source and supplies the amount of electricity needed in the process.

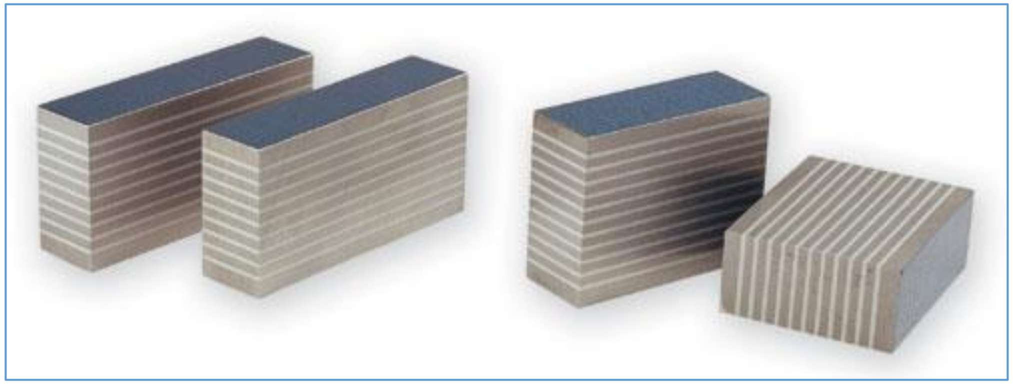
Work holding devices for EDM i.e. magnetic table, grinding vice, concentric chuck, laminated blocks etc.

Electromagnetic table:

An electromagnetic clamping system contains a housing, numerous permanent magnets, numerous low friction surfaces having a number of wheels, an end effector, an electromagnetic clamping device, first, second, and third coil systems, and a core. The end effector performs operations on a workpiece. The electromagnetic clamping device has an activated state and a deactivated state. The electromagnetic clamping device further includes a first coil system generating a first magnetic field causing normal forces on the permanent magnet unit and the clamping device; a second coil system generating a second magnetic field causing side forces on the permanent magnet unit; and a third coil system generating a third magnetic field causing a rotational force on the permanent magnet unit. The core provides access to the workpiece surface for performing operations thereon; and concentrates forces from a number of magnetic fields on the core surface contacting the workpiece surface.

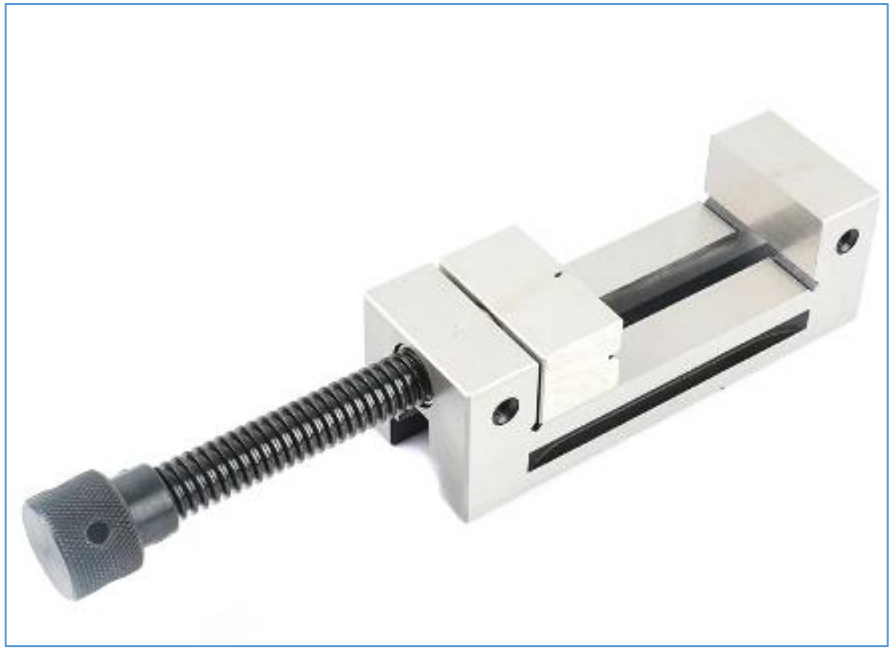
Laminated blocks:

Laminated blocks transmit the magnetic field of the chuck towards the workpiece. They can be used with any magnetic clamping system that has a parallel pole pitch. They can simply be placed loose on the magnetic chuck surface (respecting laminations direction) or can be mechanically fitted to the chuck.



EDM vise / grinding vise:

It is ground and parallel from all sides also known as grinding vise.



Machine Parameters:

The waveform is characterized by the:

- The open circuit voltage – Vo
- The working voltage – Vw
- The maximum current – Io
- The pulse on time – the duration for which the voltage pulse is applied - ton
- The pulse off time – toff
- The gap between the workpiece and the tool – spark gap - δ
- The polarity – straight polarity – tool (-ve)
- The dielectric medium
- External flushing through the spark gap.

Knowledge of grades of surface textures

(VDI scale)

For more details please visit: https://edmprecision.com/surface-roughness-comparison/ and https://www.engineersedge.com/catalog/product_info.php/products_id/139

An EDM surface finish is different to one produced by conventional material removal processes. Rather than exhibiting directionality, the texture is random, which is beneficial in many applications.

Surface Roughness is measured in Microns (Micrometer) which is a millionth part of a meter. Typically, surface finish is specified as 'Ra', on center line average basis. Common values of roughness of machined surface's lies between 1.6 to 6.3 Microns.

Ra and RMS are both representations of surface roughness, but each is calculated differently. Ra is calculated as the Roughness Average of a surfaces measured microscopic peaks and valleys. RMS is calculated as the Root Mean Square of a surfaces measured microscopic peaks and valleys.

VDI – is a scale often used by German machine manufacturers and quite widely used in Spark and Wire Erosion (Verein Deutscher Ingenieure, the Society of German Engineers)

EDM – Dielectric:

- In EDM, material removal mainly occurs due to thermal evaporation and melting.
- As thermal processing is required to be carried out in absence of oxygen so that the process can be controlled and oxidation avoided.
- Oxidation often leads to poor surface conductivity (electrical) of the workpiece hindering further machining.
- Hence, dielectric fluid should provide an oxygen free machining environment.
- Further it should have enough strong dielectric resistance so that it does not breakdown electrically too easily.
- But at the same time, it should ionize when electrons collide with its molecule.
- Moreover, during sparking it should be thermally resistant as well.
- Generally kerosene and de-ionized water is used as dielectric fluid in EDM.
- Tap water cannot be used as it ionizes too early and thus breakdown due to presence of salts as impurities occur.
- Dielectric medium is generally flushed around the spark zone.
- It is also applied through the tool to achieve efficient removal of molten material.
- Three important functions of a dielectric medium in EDM:

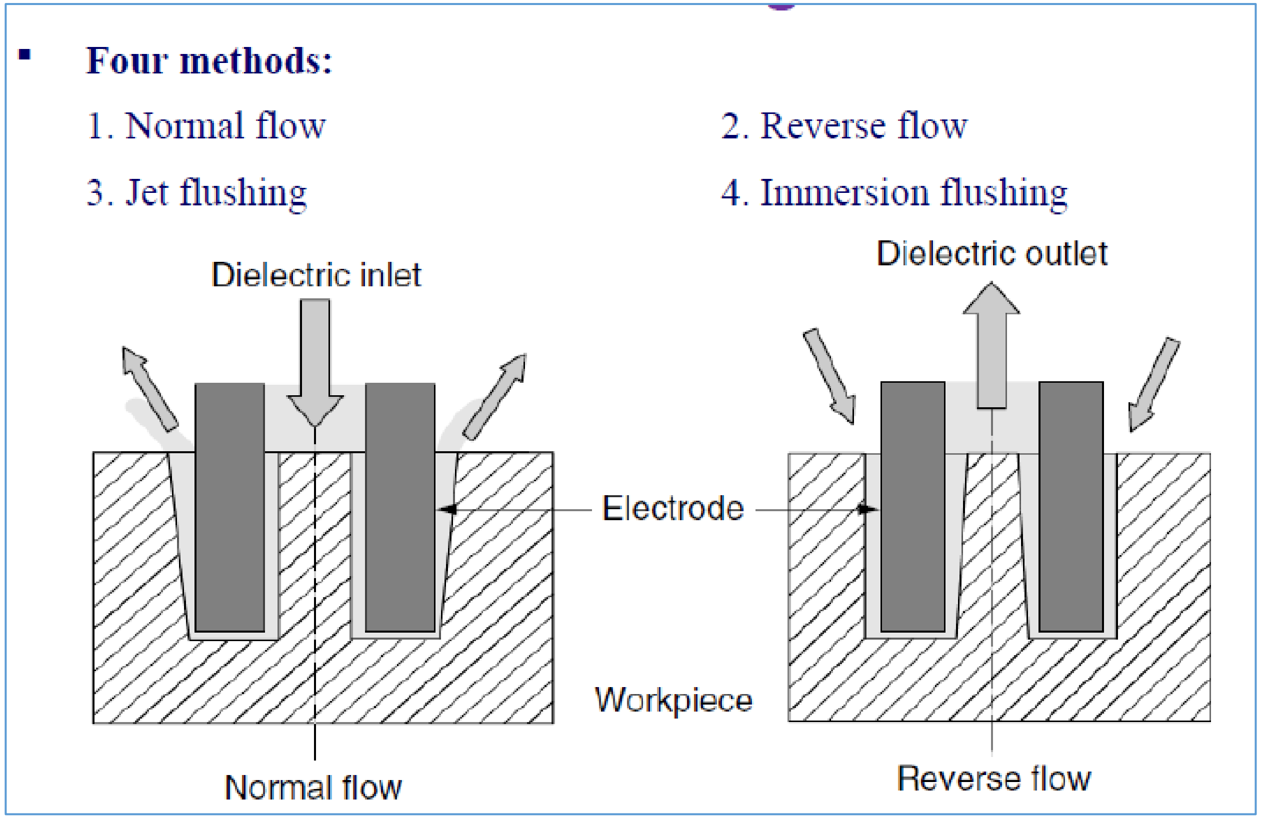
  1. insulates the gap between the tool and work, thus preventing a spark to form until the gap voltage are correct.
  2. Cools the electrode, workpiece and solidifies the molten metal particles.
  3. Flushes the metal particles out of the working gap to maintain ideal cutting conditions, increase metal removal rate.

- It must be filtered and circulated at constant pressure.
- The main requirements of the EDM dielectric fluids are adequate viscosity, high flash point, good oxidation stability, minimum odor, low cost, and good electrical discharge efficiency.
- For most EDM operations kerosene is used with certain additives that prevent gas bubbles and de-odoring.
- Silicon fluids and a mixture of these fluids with petroleum oils have given excellent results.
- Other dielectric fluids with a varying degree of success include aqueous
- Solutions of ethylene glycol, water in emulsions, and distilled water.

EDM – Flushing:

For more details please visit: http://www.reliableedm.com/Complete%20EDM%20Handbook/Complete%20EDM%20Handbook_12.pdf

- One of the important factors in a successful EDM operation is the removal of debris (chips) from the working gap.
- Flushing these particles out of the working gap is very important, to prevent them from forming bridges that cause short circuits.
- EDMs have a built-in power adaptive control system that increases the pulse spacing as soon as this happens and reduces or shuts off the power supply.
- Flushing – process of introducing clean filtered dielectric fluid into spark gap.
- If flushing is applied incorrectly, it can result in erratic cutting and poor machining conditions.
- Flushing of dielectric plays a major role in the maintenance of stable machining and the achievement of close tolerance and high surface quality.
- Inadequate flushing can result in arcing, decreased electrode life, and increased production time.



Normal flow (Majority)

- Dielectric is introduced, under pressure, through one or more passages in the tool and is forced to flow through the gap between tool and work.
- Flushing holes are generally placed in areas where the cuts are deepest.
- Normal flow is sometimes undesirable because it produces a tapered opening in the workpiece.

Reverse flow:

- Particularly useful in machining deep cavity dies, where the taper produced using the normal flow mode can be reduced.
- The gap is submerged in filtered dielectric, and instead of pressure being applied at the source a vacuum is used.
- With clean fluid flowing between the workpiece and the tool, there is no side sparking and, therefore, no taper is produced.

Jet flushing:

- In many instances, the desired machining can be achieved by using a spray or jet of fluid directed against the machining gap.
- Machining time is always longer with jet flushing than with the normal and reverse flow modes.

Immersion flushing:

- For many shallow cuts or perforations of thin sections, simple immersion of the discharge gap is sufficient.
- Cooling and debris removal can be enhanced during immersion cutting by providing relative motion between the tool and workpiece.
- Vibration or cycle interruption comprises periodic reciprocation of the tool relative to the workpiece to effect a pumping action of the dielectric.
- Synchronized, pulsed flushing is also available on some machines.
- With this method, flushing occurs only during the non-machining time as the electrode is retracted slightly to enlarge the gap.
- Increased electrode life has been reported with this system.

Health and safety related to EDM shop

During EDM the work material is removed by a series of sparks that occur in the dielectric liquid filling the gap between the tool-electrode and workpiece, Figure 3. EDM has several hazard potentials which are:

- Hazardous smoke, vapors, and aerosols
- Decomposition products and heavy metals
- Hydrocarbon dielectrics affect the skin.
- Sharp-edge metallic particles damages the skin
- Possible fire hazard and explosions
- Electromagnetic radiation

In EDM, the total aerosols and vapor concentrations exceed the limits of 5 mg/m3 if no protective measures are taken. Fumes, vapors, and aerosols depend on the material removal process, the dielectric, and the work material. In this regard:

- Die sinking generates more fumes and aerosols than wire EDM
- Material composition that contain toxic or health attacking substances such as nickel

- Dielectric type, composition, and viscosity influence the fume and vapor. Lower viscosity produces less fumes and vapors.
- The level of the dielectric over the erosion spot condenses and absorbs a considerable part of the vapor and fumes in the dielectric itself. (80 mm is recommended).

During EDM using mineral oils or organic dielectric fluids generates hazardous fumes such as polycyclic aromatic hydrocarbons (PAH), benzene, vapor of mineral oil, mineral aerosols, and other products are generated by dissociation of oil and its additives. Hydrocarbon dielectrics, generate the same vapors and aerosols except PAH and benzene. Fore water based solvents, normally used in wire EDM, carbon monoxide, nitrous oxide, ozone, and harmful aerosols are formed. There is an increasing demand for exploring methods that reduce or eliminate the adverse effect of the working fluid dielectric of EDM.

Due to erosion of the workpiece and tool electrodes, inorganic substances such as tungsten carbide, titanium carbide, chromium, nickel, molybdenum, and barium are released and condensate in the air. Emissions of organic materials are generated by the vaporization of the dielectrics. Additionally, the rising smoke carries organic components from substances in the dielectric liquid. The erosion slurry contains eroded workpiece and tool material and solid decomposition products of the dielectric.

Protective measures:

In order to reduce the possible hazards that may arise due machining by EDM, the following measures should be strictly followed:

- Reduce air pollution to the permissible extent using suitable filters • Incorporate a dielectric cleaning and recalculating system
- Keep the temperature of the media at 15o C blow flashing
- Reduce the emitted electromagnetic radiation by proper shielding of the machine • Reduce the possibility of fire hazard
- Use level sensors for the dielectric level
- Avoid dielectrics with flashing point of 65o C
- Apply a suitable disposal of the wastes
- Raise the operator awareness to the risk of high voltage to avoid severe injury or even death

Knowledge of classes of fire.

For more details please visit: http://www.strikefirstusa.com/2016/05/five-classes-of-fires-fire-extinguishers-stop-them/

Not all fires are the same. Fires are classified by the types of materials that are burning. Extinguishers are labeled to correspond to the classes of fires they are designed to fight. If you use the wrong type of fire extinguisher on a fire, you can, in fact, make matters worse. Understanding the four different fire classifications is therefore very important.

Class A:

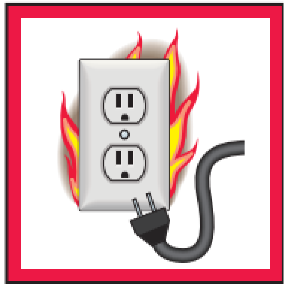
Fires involve ordinary combustibles, like wood, paper, cloth, trash, and plastics. They do not contain metals, combustible liquids, or electricity. (Class A fires generally leave Ashes.)

Class B:

Fires involve flammable liquids. Typical flammable liquids are gasoline, oil, grease, paint, and acetone. Class B fires can be very difficult to control because they involve burning nonmetals in a liquid state. This classification also includes flammable gases. (Class B fires generally involve materials that Boil or Bubble.)

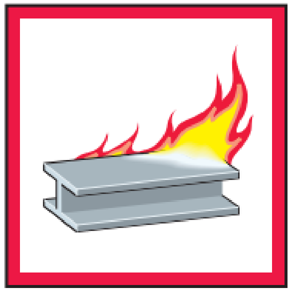
Class C:

Fires involve electrical equipment. Thus, electricity is always present. It is often combined with combustible materials. An additional hazard of a Class C fire is the potential for electric shock while fighting the fire. If possible, always turn off the source of electricity before fighting an electrical fire. The fire may be extinguished, but if the electricity is not turned off, the fire may rekindle. (Class C fires deal with electrical Current.)

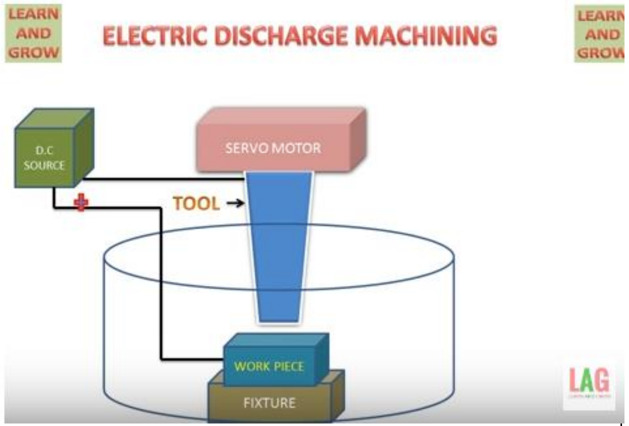
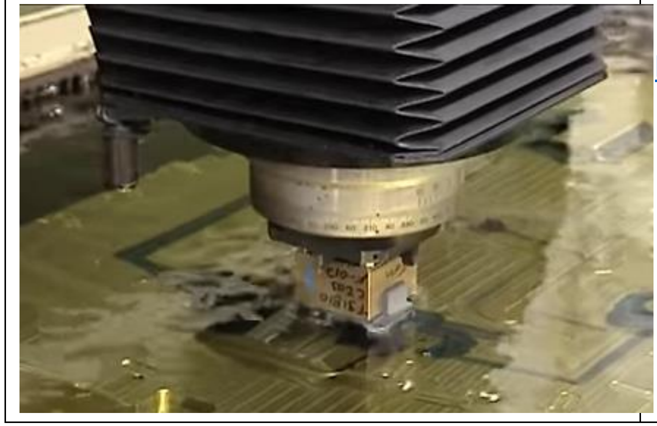


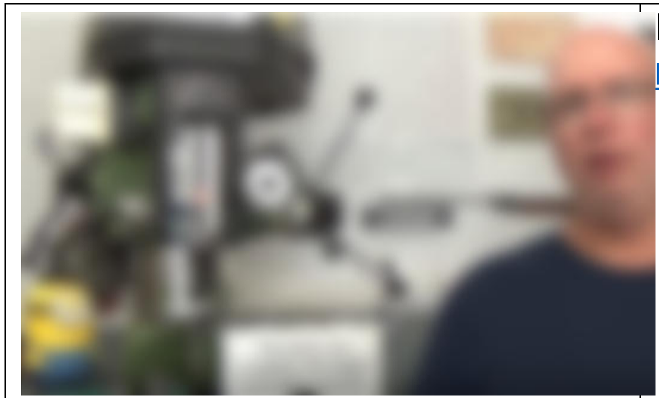
Class D:

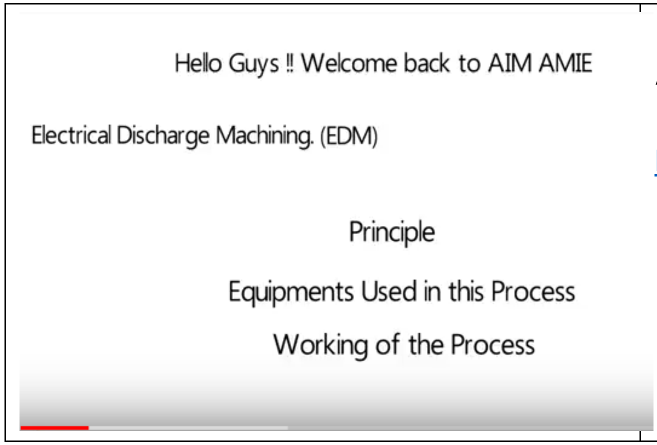
Fires involve combustible metals. Potassium, sodium, aluminum, and magnesium burn at extremely high temperatures. Unless you work in a laboratory or in an industry that uses these materials, it is unlikely you'll have to deal with Class D fires. They are uncommon in agriculture.



VIDEOS:

	Electric Discharge Machining (English) https://www.youtube.com/watch?v=kSIFiWSRpBw
	Electrical Discharge Machining https://www.youtube.com/watch?v=L1D5DLWWMp8

	ELECTRICAL DISCHARGE MACHINING EDM, MARC LECUYER https://www.youtube.com/watch?v=ProB4LpswPA
	EDM Machine Working https://www.youtube.com/watch?v=YCAp7fz8Qi8

	How An Electrical Discharge Machining Works??? ||Engineer's Academy|| https://www.youtube.com/watch?v=UAvshdSXnKU

DIES AND MOULDS MAKER

Module-3

LEARNER GUIDE

National Vocational Certificate Level 3

Version 1 - August, 2019

Module 3: 071500971 Perform Wire Cut Operations

Objective of the module: This unit involves the skills and knowledge required for an individual to perform wire cut operations as per standard procedures..

Duration: 130 Hrs **Theory:** 10 Hrs **Practical:** 120 Hrs

Learning Unit	Learning Outcomes	Learning Elements	Materials Required
LU1: **Set machine programing**	**The trainee will be able to:** Generate a CAD drawing as per job specification Export the drawing in machining format Import the file into machine panel Set the machine parameters as per job specifications	Working principle and applications of Wire cut machine. Major functional parts of a wire cut. **Parts:** bed, head, control panel, wire drum etc. Use of CAD to generate 2D drawing Preparing drawing for machining i.e. allocate start / end points, adding wire offset values, save in machining format, import export drawing, loading file on machine etc. Knowledge of setting machine parameters i.e. current, voltage, on time, off time etc.	Computer with CAD software CNC wire cut machine 2D drawing for a specific job to cut Portable storage device
LU2: **Set Wire**	**The trainee will be able to:** Select appropriate wire as per job & machine specification Mount the wire as per standard procedure Set the wire tension as	Material, diameter and application of wire. **Material:** Molybdenum alloy, Brass, copper **Diameter**: 0.1, 0.15, 0.18, 0.2 mm Know the method of winding wire on drum. Method of tensioning the wire Method of setting vertical alignment of wire	Wire cut machine Wire loop Wire aligning block Magnet blocks

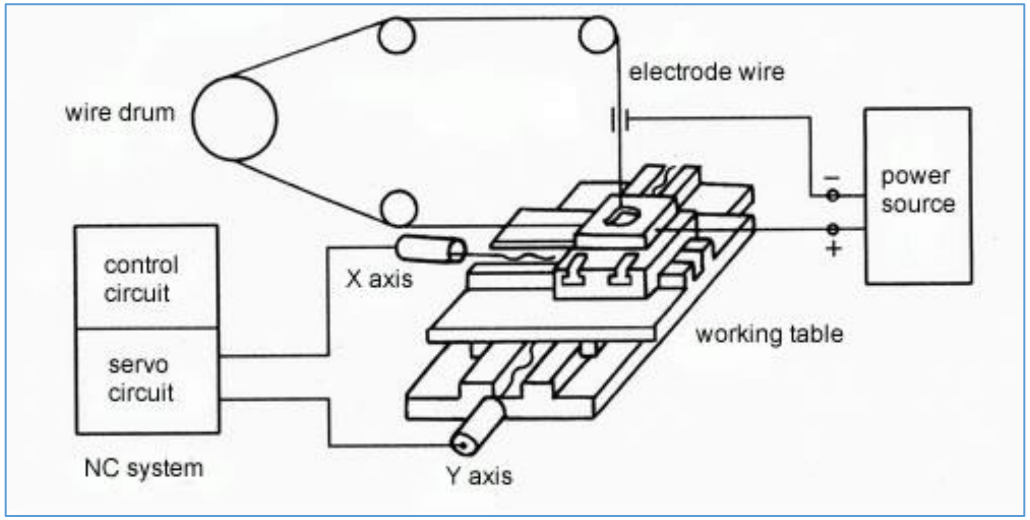
	per standard procedure Align the wire with reference to the axis.		
LU3: **Set di-electric fluid attachments**	**The trainee will be able to:** Select appropriate work holding devices to clamp work piece Mount the work piece as per standard procedure Identify and locate di-electric nozzle if required	Knowledge of work holding devices for wire cut. Function of Di-electric fluid	Wire cut machine Di-electric fluid Flushing nozzles with magnetic stand
LU4: **Set machine parameters according to the job**	**The trainee will be able to:** Set wire speed according to the surface finish & work piece thickness Set current according to the surface finish & work piece thickness Set On and OFF time according to the surface finish & work piece thickness.	Knowledge of wire cut machine parameters and its effects. **Parameter:** On time, off time, current etc. Knowledge of drawing and machine coordinates (Axis difference in drawing and machine) Know the effects of current, on time, off time etc. on the surface finish.	Wire cut machine MS work piece

LU5: **Carryout machining process**	**The trainee will be able to:** Set the wire at start point Turn On dielectric fluid Put the protective guards on machine table	Working practice on a wire cut machine Method of setting wire outside or inside the work piece. Method of resetting wire due to wire breakage Safe operating procedure for operating a wire cut machine.	Wire cut machine MS / hardened carbon steel Wire aligning block Wire Di-electric fluid
LU6: **Perform final inspection**	**The trainee will be able to:** Prepare the work piece for inspection Visually Inspect the work piece Manage the required measuring tools Perform the required inspection as per drawing	How to prepare the work piece for inspection Use of inspection tools Knowledge of interpreting drawings	Inspection tools
LU7: **Demonstrate safe working practice and housekeeping**	**The trainee will be able to:** Select & use appropriate PPEs. Maintain cleanliness at the workplace	Hazards associated to wire cut machine Health and safety relevant to wire cut machine	
	Ensure relevant safety procedure for Wire cut operations		

Examples and illustrations

Wire Cut Electric Discharge Machining (WEDM)
For more details please visit: https://pdfs.semanticscholar.org/598b/d32f73a82df720517b84f0db98dd6c1b9b2e.pdf
And http://www.reliableedm.com/Complete%20EDM%20Handbook/Complete%20EDM%20Handbook_2.pdf
The Wire Electric Discharge Machining (WEDM) is a variation of EDM and is commonly known as wire-cut EDM or wire cutting. In this process, a thin metallic wire is fed on-to the workpiece, which is submerged in a tank of dielectric fluid such as deionized water. This process can also cut plates as thick as 300mm and is used for making punches, tools and dies from hard metals that are difficult to machine with other methods. The wire, which is constantly fed from a spool, is held between upper and lower diamond guides. The guides are usually CNC-controlled and move in the x–y plane. On most machines, the upper guide can move independently in the z–u–v axis, giving it a flexibility to cut tapered and transitioning shapes (example: square at the bottom and circle on the top). The upper guide can control axis movements in x–y–u–v–i–j–k–l–. This helps in programming the wire-cut EDM, for cutting very intricate and delicate shapes.

In the wire-cut EDM process, water is commonly used as the dielectric fluid. Filters and de-ionizing units are used for controlling the resistivity and other electrical properties. Wires made of brass are generally preferred molybdenum alloy and copper wires are also widely used. The water helps in flushing away the debris from the cutting zone. The flushing also helps to determine the feed rates to be given for different thickness of the materials. The schematic of wire cut EDM is shown in Figure.



Working principle of Wire EDM.
For more details please visit: http://www.reliableedm.com/Complete%20EDM%20Handbook/Complete%20EDM%20Handbook_2.pdf

The Spark Theory on a wire EDM is basically the same as that of the vertical EDM process. In wire EDM, the conductive materials are machined with a series of electrical discharges (sparks) that are produced between an accurately positioned moving wire (the electrode) and the workpiece. High frequency pulses of alternating or direct current is discharged from the wire to the workpiece with a very small spark gap through an insulated dielectric fluid (water).

Many sparks can be observed at one time. This is because actual discharges can occur more than one hundred thousand times per second, with discharge sparks lasting in the range of 1/1,000,000 of a second or less. The volume of metal removed during this short period of spark discharge depends on the desired cutting speed and the surface finish required.

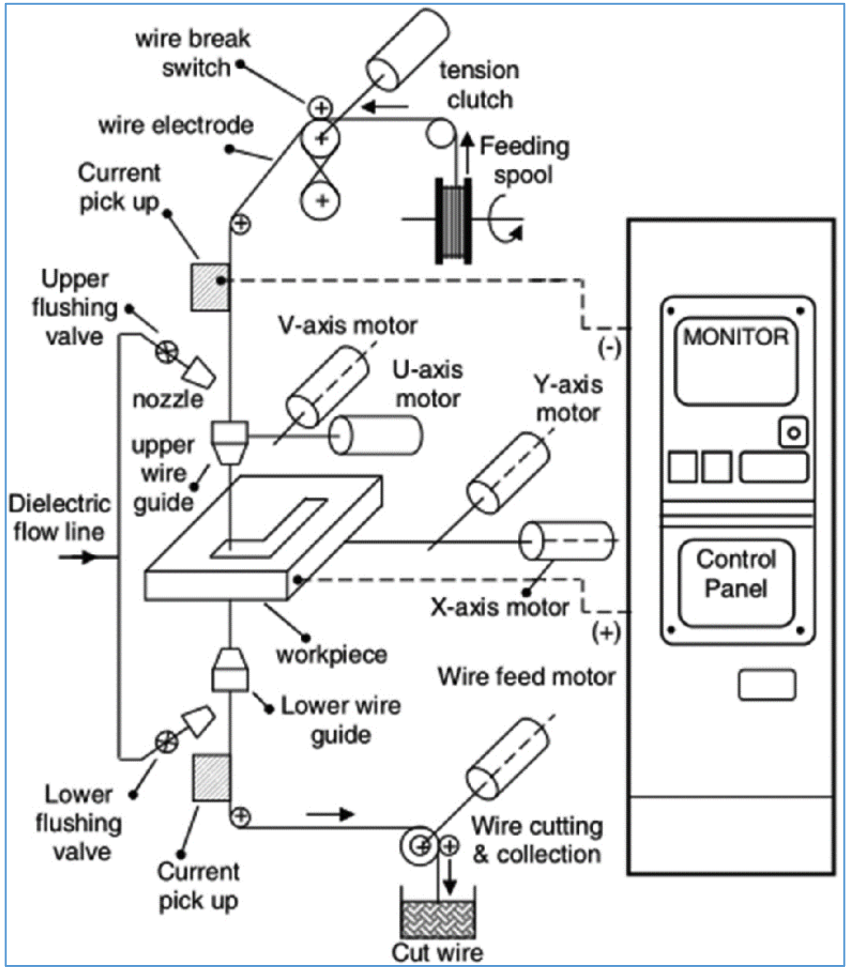
The heat of each electrical spark, estimated at around 15,000° to 21,000° Fahrenheit, it erodes away a tiny bit of material that is vaporized and melted from the workpiece. (Some of the wire material is also eroded away) These particles (chips) are flushed away from the cut with a stream of de-ionized water through the top and bottom flushing nozzles. The water also prevents heat build-up in the workpiece. Without this cooling, thermal expansion of the part would affect size and positional accuracy. Keep in mind that it is the ON and OFF time of the spark that is repeated over and over that removes material, not just the flow of electric current.

Applications of Wire cut EDM:

Wire EDM is used for cutting aluminum, brass, copper, carbides, graphite, steels and titanium. A schematic of the cutting through wire EDM is shown in Fig. 3.11.2. The wire material varies with the application requirements. Example: for quicker cutting action, zinc-coated brass wires are used while for more accurate applications, molybdenum wires are used.
The process is used in the following areas:

- Aerospace, Medical, Electronics and Semiconductor applications
- Tool & Die making industries.
- For cutting the hard Extrusion Dies
- In making Fixtures, Gauges & Cams
- Cutting of Gears, Strippers, Punches and Dies
- Manufacturing hard Electrodes.
- Manufacturing micro-tooling for Micro-EDM, Micro-USM and such other micromachining applications.

Major functional parts of a wire cut.



Use of CAD to generate 2D drawing:

For more details please visit: https://web.iit.edu/sites/web/files/departments/academic-affairs/academic-resource-center/pdfs/Introduction_to_AutoCAD.pdf

A 2D CAD drawing is most commonly used in wire cut EDM. The drawing can be used directly on the machine panel or using a computer system, as the wire travels at the center of the line one of the most important features that must be in mind is wire offset values.
Programs are created and written for the center of the tool (wire) to follow the outline of the part. Let's say you are using a .010" diameter wire and it cuts a .012" slot with the power settings provided for the particular material. A .006" offset would be needed to put the part "on-size". Which side of the part (left or right) we apply the offset is determined by two factors.

1. Is the part we are saving, the male (slug), or the female (opening)?
2. Are we cutting the part in a clockwise or counterclockwise direction?

Using a die as an example, the same program can be used to cut the die block, punch pad, stripper, and even the die shoe. By changing the offset amount, the sizes and clearances required are maintained on all the parts.

Preparing drawing for machining:

- allocate start / end points,
- adding wire offset values,
- save in machining format,
- import export drawing,
- loading file on machine

Setting machine parameters:

For more details please visit: https://www.researchgate.net/publication/320491280_Effect_of_wire-EDM_process_parameters_on_cutting_speed_of_AL6061_hybrid_composite

and
https://www.researchgate.net/publication/302977661_Optimization_of_the_machining_parameters_for_EDM_wire_cutting_of_Tungsten_Carbide

Wire-cut electrical discharge machining is one of the most emerging non-conventional manufacturing processes for machining hard to machine materials and intricate shapes which are not possible with conventional machining methods. This is more efficient and economical for machining hard to machine materials. The effect of various parameters and setting of various parameters at their optimal levels is very much required for manufacturers. The parameters and their effects observed are given as under.

A. Higher the pulse-on time, higher will be the energy applied there by generating more amount of heat energy during this period. Material removal rate and wire wear rate increase with increase in pulse on time whereas surface finish will decrease.

B. Reducing pulse off time can increase cutting speed, by allowing more productive discharges per unit time. However, reducing off time, can overload the wire, causing wire breaks and instability of the cut by not allowing enough time to evacuate the debris before the next discharge. **C.** Servo voltage acts as the reference voltage to control the wire advances and retracts. At higher value of SV the gap between work piece and wire becomes wider and it decreases the no of sparks, stabilizes electric discharge and the rate of machining slows down. Whereas at smaller value of SV, the mean gap becomes narrow which leads to an increase in number of electric sparks, speed up the machining rate and unstable discharge results in wire breakage.

D. Peak current is the amount of power used in discharge machining and is measured in unit of amperage. The current increases until it reaches a preset value during each pulse on time, which is known as peak current. Peak current is governed by surface area of cut. Higher peak current is applied during roughing operation and details with large surface area. MRR directly increases with increased peak current.

E. Gap voltage is also called open circuit voltage and specifies the supply voltage to be placed on the gap, greater this value, the electric discharge becomes greater. If the gap voltage increases, the peak current will also increase which leads to higher MRR (Material Removal Rate).

F. Dielectric flow rate is the rate at which the dielectric fluid is circulated. Flushing is important for efficient machining.

G. As the wire feed rate increases, the consumption of wire and cost of machining will increase. Low wire speed will cause wire breakage in high cutting speed.

H. If the wire tension is high enough the wire stays straight otherwise wire drags behind. Within considerable range, an increase in wire tension significantly increases the cutting speed and accuracy. The higher tension decreases the wire.

Material and diameter of wire.

The wire electrode is usually a spool of brass, or brass and zinc wire from .001 to .014" (.025 to .357 mm) thick. Sometimes molybdenum or tungsten wire is used. New wire is constantly fed into the gap; this accounts for the extreme accuracy and repeatability of wire EDM.

In WEDM process, the cutting performance in terms of machining speed, surface finish, dimensional accuracy and wire breakage is dependent upon the quality of the wire electrode. The performance of the wire-tool depends on the following factors:

(i) Electrical properties of the wire electrode,

(ii) Mechanical properties of the wire electrode,
(iii) Thermo Physical properties of the wire electrode,
(iv) Cross sectional size and shape of the wire electrode.

Wire possessing higher electrical conductivity is always preferred to reduce Joule heating (I2R) of the wire and failure caused thereby. The important mechanical properties required for wire electrode are tensile strength (σy), the modulus of elasticity and in some cases, the co-efficient of mechanical friction. A wire-tool material should possess a high tensile strength to withstand various forces acting along or upon it, such as forces from gas bubbles formed by the plasma of the erosion mechanism, hydraulic forces due to flushing, electrostatic force, electrodynamics force and the tensile load applied along the wire during machining.

The important thermo-physical aspects of wire tool materials are thermal conductivity, melting point and evaporation temperature. Higher values of all of those properties are desirable for minimal thermal erosion in the wire tool. High melting point and evaporation temperature substantially reduces the depth and size of the crater formed on the wire tool surface and a high thermal conductivity helps to cool the wire at a faster rate.

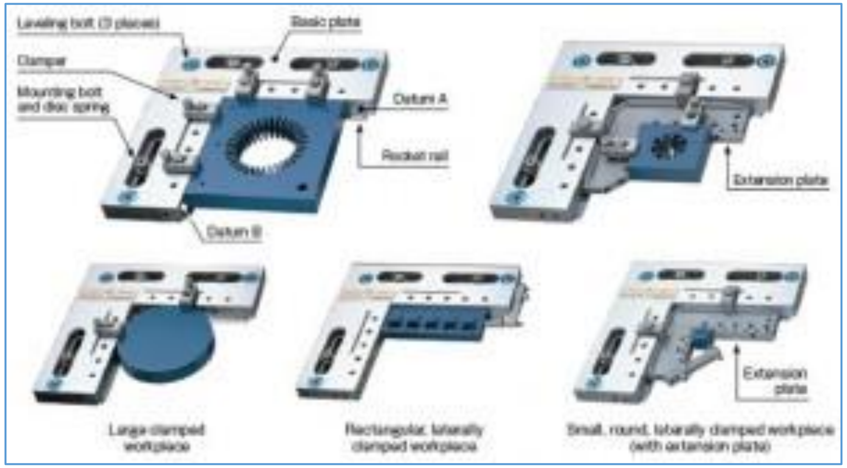
Work holding devices for wire cut.

There are many work holding devices are used for wire cut edm.

Clamps:

Wire edm vise:

Fixtures:



Extension clamps:

Function of Di-electric fluid

In general, dielectrics are electrically nonconductive but it can behave as a conducting medium under a particular potential difference applied at two different points in the medium. This potential difference, under which the molecules start breaking into atoms and atoms into free electrons and positive ions, is called the breakdown voltage. In WEDM process, a fluid dielectric, generally deionized water is used. The dielectric fluid serves as a spark conductor, concentrating the spark energy to an extremely narrow region. As soon as a spark discharge takes place, the dielectric again becomes a nonconductive medium until the required breakdown voltage is reached. The maximum potential difference that a unit thickness of a dielectric medium can withstand (without breakdown) is defined as the dielectric strength of that medium.

The major functions of the dielectric in wire-cut electrical discharge machining processes are as follows.

- It flushes away the machined particles (debris) from the machining zone to avoid short circuits and arcs.
- It acts as a medium in which the spark is built.
- It concentrates the energy of the spark. By restriction of the plasma channel, the energy density is kept high.
- It cools both the wire electrode and the work piece. Cooling of electrodes is of high importance in WEDM to avoid wire rupture.

The choice of the dielectric has been dictated by many practical considerations, complying with the following essential requirements:

- It should have a particular stable dielectric strength to meet the process requirement.
- It should deionize rapidly as soon as the spark discharge take place.

- It should have tow velocity and a good wetting capacity.
- It should be chemically neutral so as not to attack the wire-electrode, the work piece, the worktable or the dielectric container.
- The flashpoint of the dielectric must be sufficiently high to avoid any fire hazards.
- It should not emit any toxic vapor or have unpleasant odors;
- It should be stable enough to maintain its properties under temperature variations, contamination by machined debris particles and decomposition products, if any; and
- It should be easily available at a reasonable price.

The WEDM process require a dielectric with low conductivity to provide a larger spark gap as the wire electrode under tension is subjected to vibration under various disturbing forces during and after spark discharges.

Effect of process parameters.

Time ON:

All the work is done during time ON. The spark gap is bridged, current is generated and the work is accomplished. The longer the spark is sustained more is the material removal. Consequently the resulting craters will be broader and deeper; therefore the surface finish will be rougher. Obviously with shorter duration of sparks the surface finish will be better. With a positively charged work piece the spark leaves the tool and strikes the work piece resulting in the machining. Except during roughing all the sparks that leave the tool result in a microscopic removal of particles of the surface. More sparks produce much more wear; hence this process behaves quite opposite to normal processes in which the tool wears more during finishing than roughing. Electrode material too plays a significant factor in tool wear.

Time OFF:

While most of the machining takes place during time ON of the pulse, the time off during which the pulse rests and the deionization of the dielectric takes place, can affect the speed of the operation in a large way. More is the off time greater will be the machining time. But this is an integral part of the EDM process and must exist. The time off also governs the stability of the process. An insufficient off time can lead to erratic cycling and retraction of the advancing servo, slowing down the operation cycle.

Current:

The average current is the average of the amperage in the spark gap measured over a complete cycle. This is read on the ammeter during the process. The theoretical average current can be measured by multiplying the duty cycle and the peak current (max. current available for each pulse from the power supply /generator). Avg. current is an indication of the machining operation efficiency with respect to MRR. The concept of maximum peak amperage that can be applied to the electrode is an important factor. Before determining the max. Peak amperage the frontal area of the electrode minus the area of any flush holes must be determined. This setting can be fed into the CNC that controls the EDM operation.

Voltage:

The voltage used is usually a DC power source of 40 to 400Volts. An AC power source can also be used but it is usually coupled with a DC rectifier. The preset voltage determines the width of the spark gap between the leading edge of the electrode and the work piece. High voltage settings increase the gap and hence the flushing and machining.

Gap size:

This is one of the most crucial parts of the EDM system. The size of the gap is governed by the servo control system whose motion is controlled by gap width sensors. They control the motion of the ram head or the quill, which in turn governs the gap size. Typical values of the gap size are between 0.010 to 0.050 mm, although gap sizes as small as of several hundred to several thousands of micrometers can be found depending on the application, current, voltage, and the die-electric media. To maintain a constant gap size the feed rate should be equal to the MRR. The gap size governs the possibility of sparking and arcing.

Surface finish:

The EDM process produces surface that contains a layer of recast spattered metal, which is usually hard and cracked. Below this recast layer it is possible to have some surface alterations due to abusive machining. These are more pronounced when we use abusive machining conditions. The last layer is the heat affected zone or the annealed layer, which has only been heated, not melted. The depth of the recast and the heat-affected zone is determined by the heat sinking ability of the material and the power used for the cut. The altered metal zone influences the quality of the surface integrity.

Polarity:

Polarity refers to the electrical conditions determining the direction of the current flow relative to the electrode. The polarity of the electrode can be either positive or negative. Depending on the application, some electrode/work metal combination gives better results when the polarity is changed. Generally the graphite, a positive electrode gives better wear condition and negative gives better speed.

Material removal rate (MRR):

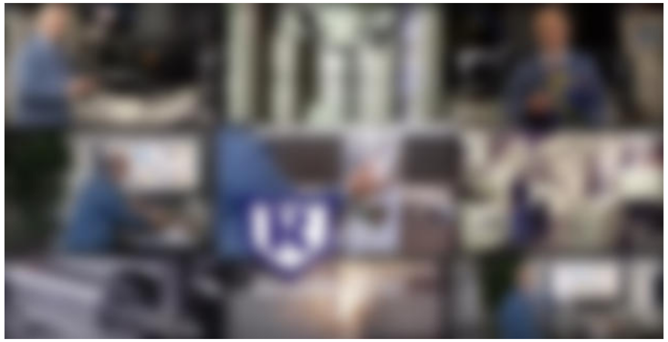
Achieving an efficient MRR is not simply a matter of good machine settings. It also includes direct energy dissipated in the EDM process. This energy can be dissipated in three ways:

- In the work piece: MRR is influenced by the thermal conductivity of the work piece. Copper for example has a low melting point but it also has a low MRR as it is a good conductor of heat. On the other hand steel has a high melting point but a low Thermal conductivity hence has a higher MRR.
- In the gap: Particles in the work gap will contribute significantly to slowing down the MRR.
- In the electrode: The MRR is also influenced by the electrode and the work piece selection.

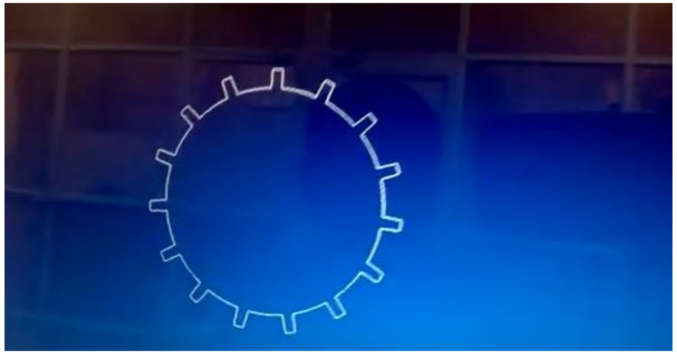
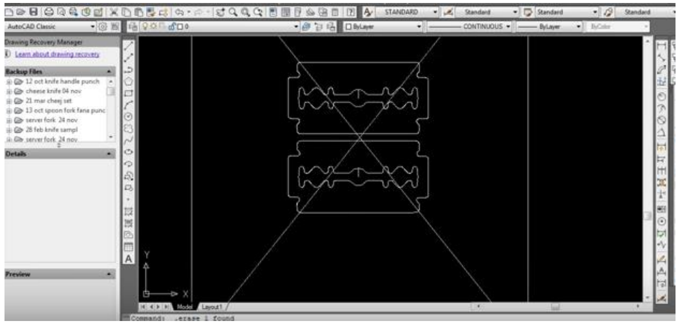
Duty factor:

This is an important parameter in the EDM process. This is given by the ratio of the ON time to the total time. If we have a high duty factor then the flushing time is very less and this might lead to the short circuit condition. A small duty factor indicates a high off time and low machining rate. Therefore there has to be a compromise between the two depending on the tool used, the workpiece and the conditions prevailing.

VIDEOS:

	How Wire EDM Works: Part 2 https://www.youtube.com/watch?v=JM-94MoOjx0

	Wire winding Kingred brand CNC Wire Cut EDM basic operation.flv https://www.youtube.com/watch?v=EtKTtC7RI3U
	Wire setting for work piece cnc wire cut Machine Shameem Sabri https://www.youtube.com/watch?v=Fw_yzjIvPow

	Generating CAD Drawing for wire cut EDM wire cut machine programing https://www.youtube.com/watch?v=k_C203UBmq8
	Setting CAD drawing and tool path cnc wire cut Machine Shameem Sabri https://www.youtube.com/watch?v=soH4V3erYnM

DIES AND MOULDS MAKER

Module-4

LEARNER GUIDE

National Vocational Certificate Level 3

Version 1 - August, 2019

Module 4: 071500972 Perform CNC lathe operations

Objective of the module: This unit involves the skills and knowledge required for an individual to perform CNC lathe operations as per standard procedures

Duration:	200 Hrs	**Theory:**	20 Hrs	**Practical:**	180 Hrs

Learning Unit	Learning Outcomes	Learning Elements	Materials Required
LU1: **Set machine Programing**	**The trainee will be able to:** Select appropriate programming software Set machine parameters as per specifications Generate program as per given specification Test run the program Make necessary correction if required Save the program	Working principle and applications of CNC lathe machine Interpretation of drawing Introduction of programing software Software: CAD CAM (i.e Master CAM, Creo) Effect of speed, feed, depth of cut etc. Programing with G and M codes Method and advantage of test run the machine Knowledge of program editing methods How to save a program	CNC lathe Machine Computer Station with required software
LU2: **Set tools**	**The trainee will be able to:** Check and verify the pneumatic pressure & coolant Select appropriate tools	Purpose of using pneumatic / hydraulic pressure and coolant. Knowledge of lathe machine tools according to operations. **Tools:** turning, facing, boring, threading and parting Method of setting tools on turret.	CNC lathe machine Carbide inserts with holder Threading tool Boring tool Parting tool

	Set the tools into the turret as per standard procedure		Turning tool
LU3: **Set workpiece**	**The trainee will be able to:** Select the appropriate clamping device (chuck ,collet) according to the workpiece Perform dialing of workpiece according to the standard procedure Set workpiece zero reference.	Method of dialing the workpiece. Standard procedure for workpiece zero setting. Setting of machining parameters i.e. speed, feed depth of cut etc.	MS shaft Cutting tools
LU4: **Carry out machining process**	**The trainee will be able to:** Ensure proper synchronization between machine control unit and part program file as per standard procedure Control the feed speed and override of machine	Know the methods and objectives of feed, speed and override. Method of machine execution i.e. single block or Auto. Lathe machine operation sequence and practice.	CNC lathe MS / Aluminum shaft Lathe machine tools

	before operating according to the prescribe procedure. Switch machine to execution mode (single block or Auto) as per prescribed method and start machining Compare the block wise movements of machine sequence thoroughly during operation of machine according to the part program.		
LU5: **Perform final inspection**	**The trainee will be able to:** Prepare the work piece for inspection Visually Inspect the work piece Manage the required measuring tools Perform the required	Knowledge of use of inspection tools i.e. Vernier caliper, micrometer, dial gauges etc. Interpretation of drawing.	Class room Workshop Any real or realistic work environment

	inspection as per drawing		
LU6: **Demonstrate safe working practice & housekeeping**	**The trainee will be able to:** Select & use appropriate PPEs. Maintain cleanliness at the workplace Ensure relevant safety procedure for CNC Lathe operations	Knowledge of PPEs	Class room Workshop Any real or realistic work environment

Examples and illustrations

Working principle and applications of CNC lathe machine

For more details please visit: https://mosafavi.iut.ac.ir/sites/mosafavi.iut.ac.ir/files/files_course/cnc_1_0.pdf

Definition of CNC machine:

Computer Numeric Control (CNC) is the automation of machine tools that are operated by precisely programmed commands encoded on a storage medium (computer command module, usually located on the device) as opposed to controlled manually by hand wheels or levers, or mechanically automated by cams alone. Most NC today is computer (or computerized) numerical control (CNC), in which computers play an integral part of the control.

CNC lathe machine

Lathes are machines that cut work pieces while they are rotated. CNC lathes are able to make fast, precision cuts, generally using index able tools and drills. They are particularly effective for complicated programs designed to make parts that would be infeasible to make on manual lathes. CNC lathes have similar control specifications to CNC mills and can often read G-code as well as the manufacturer's proprietary programming language. CNC lathes generally have two axes (X and Z), but newer models have more axes, allowing for more advanced jobs to be machined.

CNC SYSTEM ELEMENTS

A typical CNC system consists of the following six elements

- Part program
- Program input device
- Machine control unit
- Drive system
- Machine tool

ADVANTAGES:

1. CNC machines can be used continuously 24 hours a day, 365 days a year and only need to be switched off for occasional maintenance.
2. CNC machines are programmed with a design which can then be manufactured hundreds or even thousands of times. Each manufactured product will be exactly the same.
3. Less skilled/trained people can operate CNCs unlike manual lathes / milling machines etc.
4. CNC machines can be updated by improving the software used to drive the machines.

5. Training in the use of CNCs is available through the use of ‘virtual software’. This is software that allows the operator to practice using the CNC machine on the screen of a computer. The software is similar to a computer game.
6. CNC machines can be programmed by advanced design software such as Pro/engineer, Uni-Graphics, Master cam etc. enabling the manufacture of products that cannot be made by manual machines, even those used by skilled designers / engineers.
7. Modern design software allows the designer to simulate the manufacture of his/her idea. There is no need to make a prototype or a model. This saves time and money.
8. One person can supervise many CNC machines as once they are programmed they can usually be left to work by themselves. Sometimes only the cutting tools need replacing occasionally.
9. A skilled engineer can make the same component many times. However, if each component is carefully studied, each one will vary slightly. A CNC machine will manufacture each component as an exact match.

Interpretation of drawing

Orthographic projection and Isometric Projection:

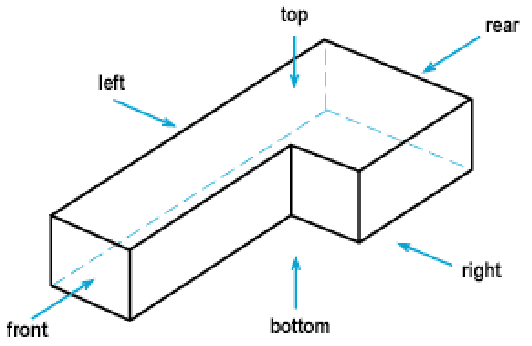
For more details please visit: http://www.iitg.ac.in/kpmech/ME111-2016/ORTHOGRAPHIC%20PROJECTIONS-1%20(2016).pdf

Orthographic projection (or orthogonal projection) is a means of representing three-dimensional object in two dimensions. It is a form of parallel projection, where all the projection lines are orthogonal to the projection plan.

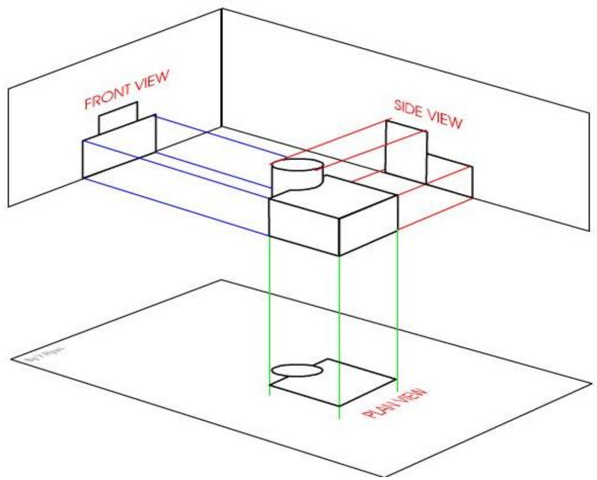
Principal views:

There are six principal views in a multi-view orthographic projection. These are the front, back, top, bottom, and left- and right-side views. A drawing can have any combination of views but the three most common views are:

- Front view
- Side view
- Top view.

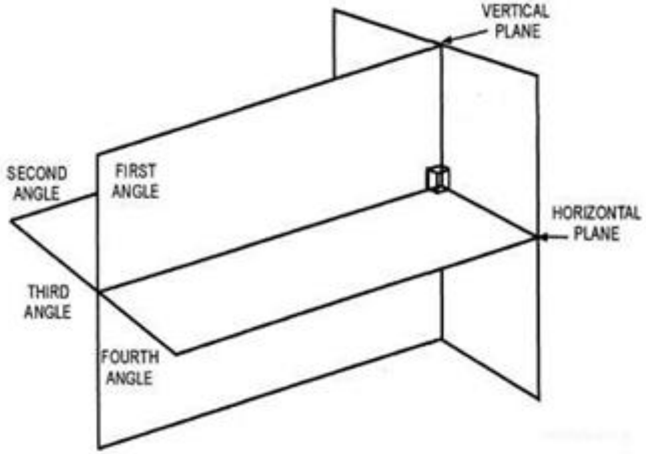


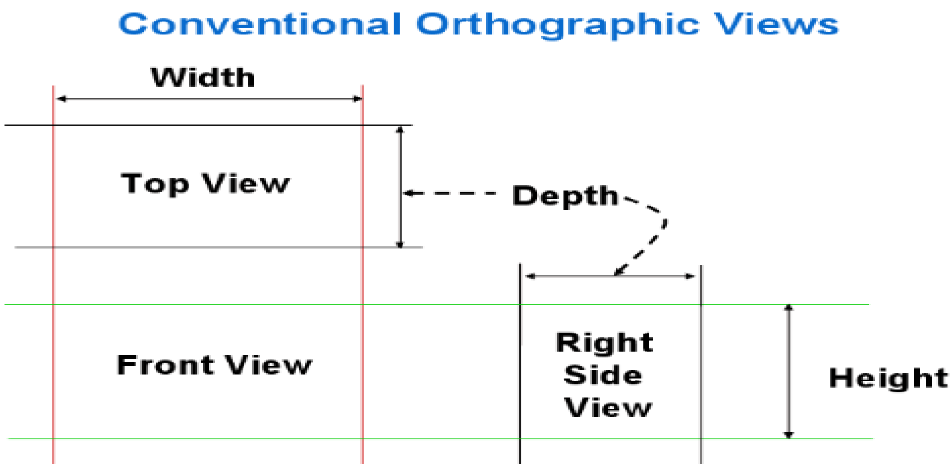
ISOMETRIC VIEW



Angles of projection

The primary planes intersect each other at right angles. The angles between the horizontal and vertical planes are described as first, second, third, and fourth angles of projection.



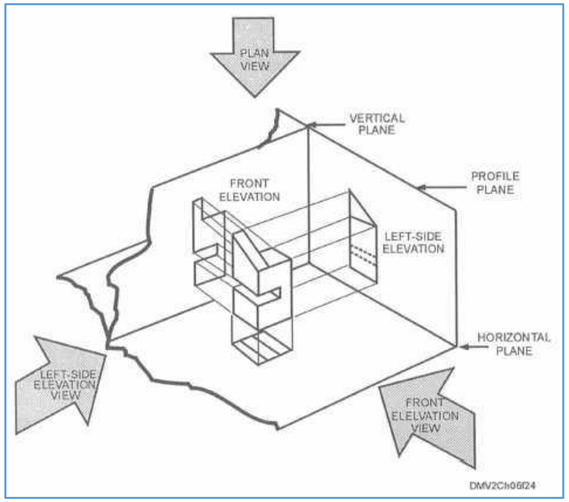


Orthographic Projections

There are two ways of drawing in orthographic - First Angle and Third Angle. They differ only in the position of the plan, front and side views.

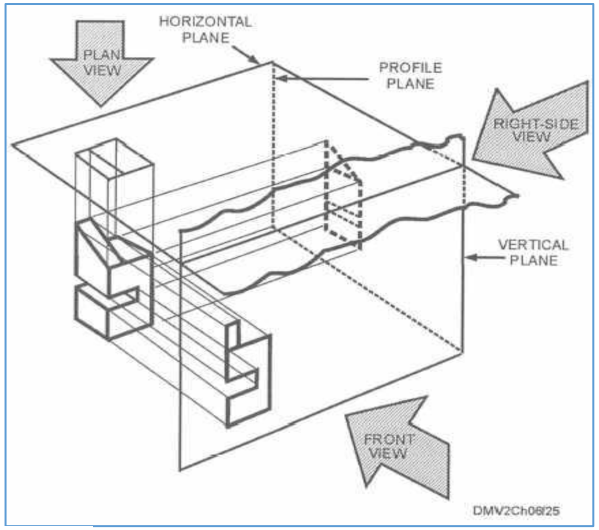
1. First-angle projections:

First-angle projection places the object on the profile plane with the vertical plane on the left and the horizontal plane on the bottom. This position locates the top view below the front view, the right-side view on the left side of the front view, and the bottom view above the front view. Because the positioning of the views initially seems illogical, first-angle projections is mostly used in asain countries.



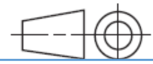
2. Third-angle projections:

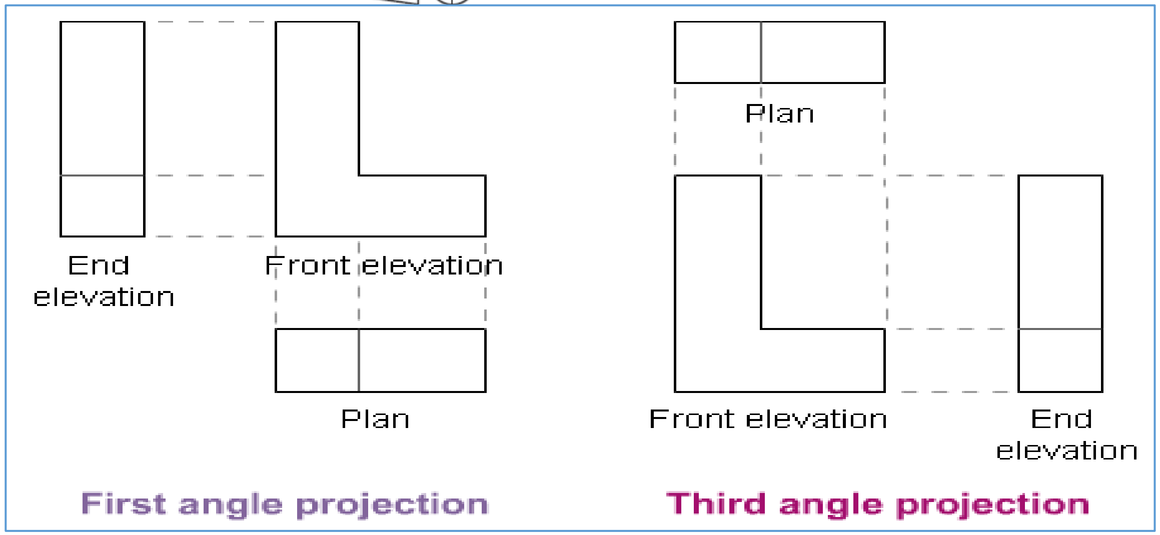
Third-angle projection places the object with the front view projected onto the vertical plane, the top view onto the horizontal plane, and the right-side view onto the profile plane. The arrangement of the three views on paper is logically sequenced. Since the late 1800s, third-angle projection has been the American standard in drafting practice.



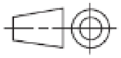
Symbol used for first angle and third angle Projection

Symbol used for first angle projection

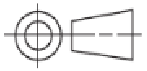




Symbol used for first angle projection

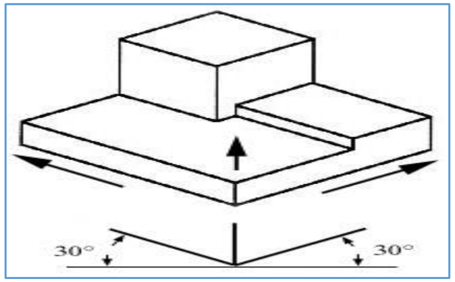


Symbol used for third angle projection



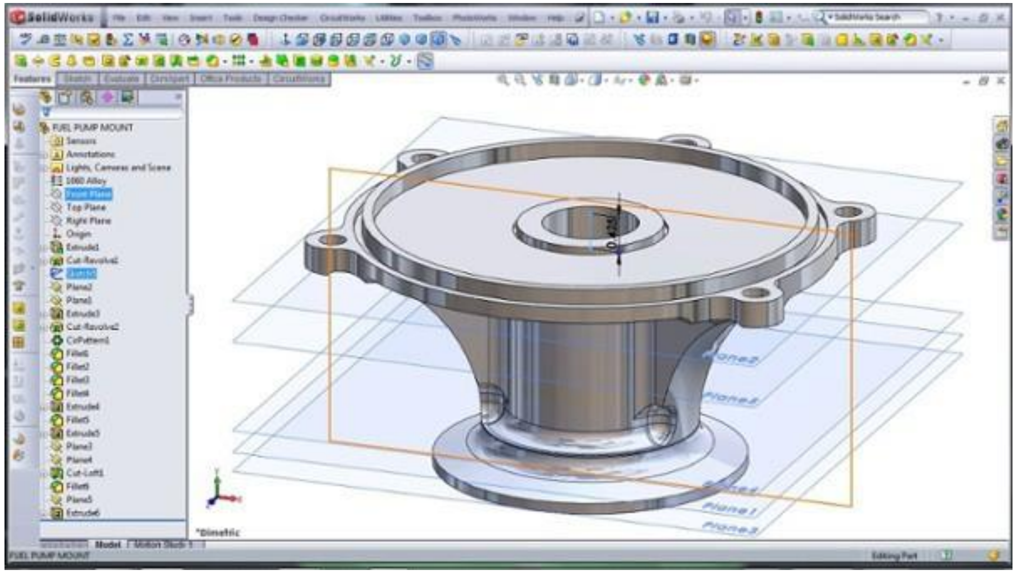
2. Isometric Projection:

The representation of the object in below figure is called an isometric drawing. This is one of a family of three-dimensional views called pictorial drawings. In an isometric drawing, the object's vertical lines are drawn vertically, and the horizontal lines in the width and depth planes are shown at 30 degrees to the horizontal.

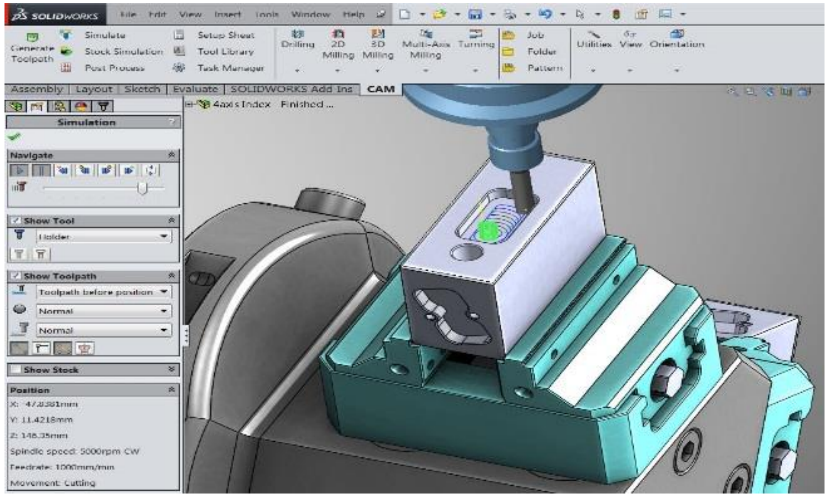


Introduction of programing software:

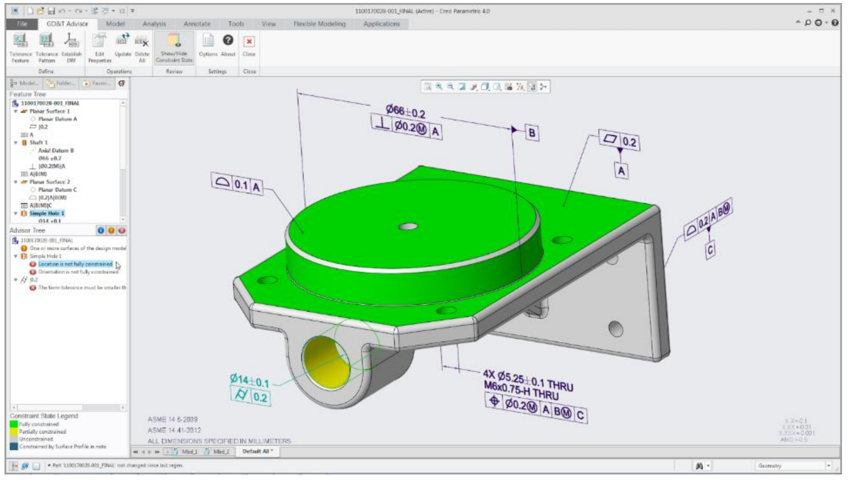
CAD: Computer Aided designing



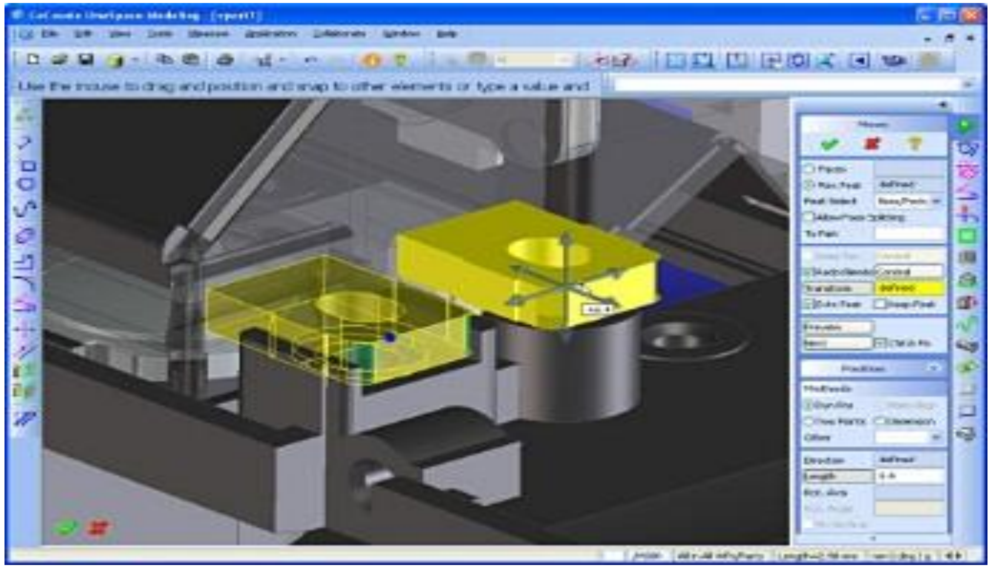
CAM: Computer Aided Machining:



Creo:



Pro E

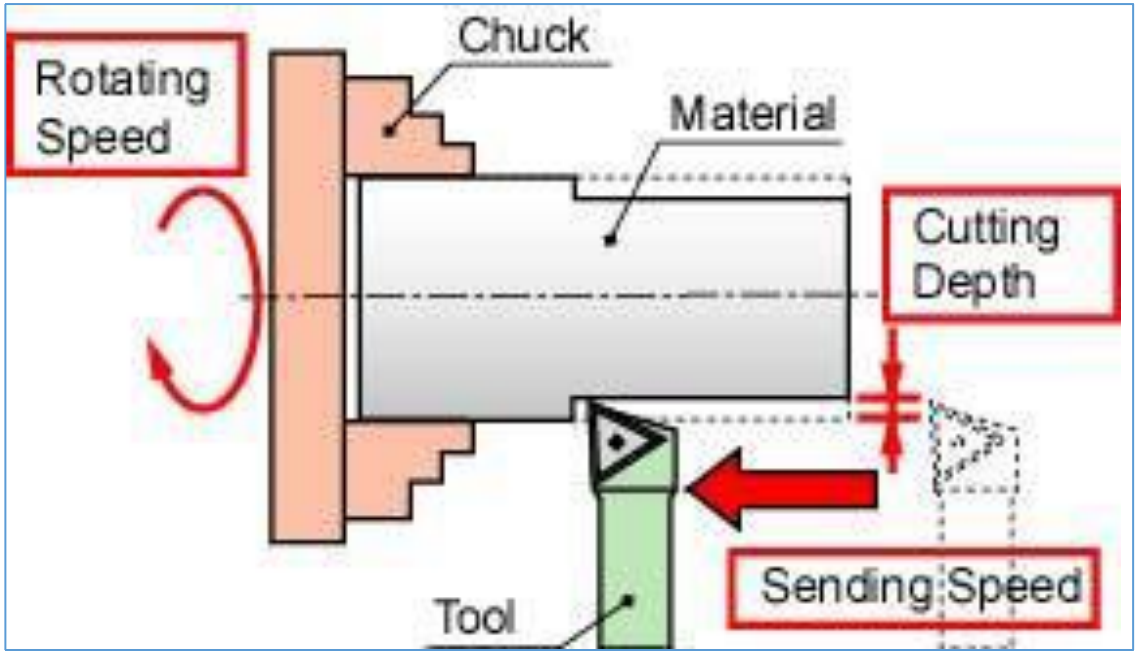


Effect of speed, feed, depth of cut etc.

Rotating Speed (Spindle speed):

It expresses with the number of rotations (rpm) of the chuck of a lathe.

When the rotating speed is high, processing speed becomes quick, and a processing surface is finely finished. However, since a little operation mistakes may lead to the serious accident.



Cutting speed:
The rate of metal removal is from the metal surface, in length, during the machining per unit time. The unit for cutting speed is m/minute. The depth of cut, the feed rate and the cutting speed are dependent of the hardness of the cutting tool material and the hardness of the cutting material:

Feed:
The distance travels by the tool toward the work piece during one rotation of part.

Cutting speed and feed determines the surface finish, power requirements, and material removal rate.

Table for Cutting speed and feed chart for HSS cutting tool

Material Being Machined	Feed (mm/rev)	Cutting Speed (m/min)
Aluminium	0.2-1.0	70-100
Brass	0.2-1.5	60-90
Cast iron	0.15-0.7	18-25
Mild Steel	0.2-1.0	30-38
Medium Carbon Steel	0.15-0.7	21-30
Alloy Steel	0.08-0.3	12-20

The primary factor in choosing feed and speed is the material to be cut. However, one should also consider material of the tool, rigidity of the work piece, size and condition of the lathe, and depth of cut.

Spindle Speed

To calculate the proper spindle speed, divide the desired cutting speed by the circumference of the work. Experiment with feed rates to achieve the desired finish.

Where: n = Number of revolution (RPM)

V = Cutting speed of material

D =Diameter of work piece

Solve the following

Q - Calculate the spindle speed for a work of diameter 50mm, for material of aluminum. See cutting speed table for specific material as reference.

Feed

$F = f \times n$

Where: F = feed rate, (mm/min)

f = feed (mm/rev)

n = RPM

Depth of Cut

$D0 - Df = 2d$

Where: Df = final diameter

Do = Original diameter

d = depth of cut

Programing with G and M codes

For more details please visit: https://academy.titansofcnc.com/files/Fundamentals_of_CNC_Machining.pdf

Needed by a CNC in terms of G and M codes

- Preparatory Information: units, incremental or absolute positioning
- Coordinates: X, Y, Z, (I, J, K)
- Machining Parameters: Feed rate and spindle speed
- Coolant Control: On/Off, Flood, Mist
- Tool Control: Tool and tool parameters
- Cycle Functions: Type of action required
- Miscellaneous Control: Spindle on/off, direction of rotation, stops for part movement
- This information is conveyed to the machine through a setoff instructions arranged in a desired sequence – Program.

G – Codes for CNC

Codes that begin with 'G' are called preparatory words because they prepare the machine for a certain type of motion.

M – Codes for CNC

Control machine auxiliary options like coolant and spindle direction. Only one **M-code** can appear in each block of code.

Details of some common G and M codes.

Codes	Category	Functions
MotionG00	Move in a straight line at rapids speed.	XYZ of endpoint
G01	Motion	Move in a straight line at last speed commanded by a feed rate
G02	Motion	Clockwise circular arc at feed rate
G03	Motion	Counter-clockwise circular arc at feed rate
G04	Motion	Dwell: Stop for a specified time.
G10	Compensation	Programmable parameter input
G17	Coordinate	Select X-Y plane
G18	Coordinate	Select X-Z plane
G19	Coordinate	Select Y-Z plane
G20	Coordinate	Program coordinates are **inches**

G21	Coordinate	Program coordinates are **mm**
G27	Motion	Reference point return check
G28	Motion	Return to home position
G29	Motion	Return from the reference position
G30	Motion	Return to the 2nd, 3rd, and 4th reference point
G32	Canned	Constant lead threading (like G01 synchronized with spindle)
G33	Canned	Threading
G40	Compensation	Tool cutter compensation off (radius comp.)
G41	Compensation	Tool cutter compensation left (radius comp.)
G42	Compensation	Tool cutter compensation right (radius comp.)
G43	Compensation	Apply tool length compensation (plus)
G44	Compensation	Apply tool length compensation (minus)
G49	Compensation	Tool length compensation cancel
G50	Compensation	Reset all scale factors to 1.0
G51	Compensation	Turn on scale factors
G52	Coordinate	Local work shift for all coordinate systems: add XYZ offsets
G53	Coordinate	Machine coordinate system (cancel work offsets)
G54	Coordinate	Work coordinate system (1st Work piece)
G55	Coordinate	Work coordinate system (2nd Work piece)
G56	Coordinate	Work coordinate system (3rd Work piece)
G57	Coordinate	Work coordinate system (4th Work piece)
G58	Coordinate	Work coordinate system (5th Work piece)
G59	Coordinate	Work coordinate system (6th Work piece)
G61	Other	Exact stop check mode
G62	Other	Automatic corner override
G63	Other	Tapping mode
G64	Other	Best speed path
G65	Other	Custom macro simple call
G70	Canned	Program coordinates are **inches**(in some machines G71 use for turning cycle)
G71	Canned	Program coordinates are **mm**
G72	Canned	Rough Facing Cycle

G73	Canned	Pattern Repeating Cycle
G74	Canned	Peck Drilling Cycle
G75	Canned	Grooving Cycle
G76	Canned	Threading Cycle
G80	Canned	Cancel canned cycle
G81	Canned	Turning Cycle (in some CNC lathe G71 is also use for the same)
G83	Canned	Face drilling cycle
G84	Canned	Drilling cycle
G86	Canned	Boring canned cycle, spindle stop, rapid out
G87	Canned	Side Drilling Cycle
G88	Canned	Side Tapping Cycle
G89	Canned	Side Boring Cycle
G90	Coordinate	Absolute position
G91	Coordinate	Incremental position
G92	Coordinate	Thread Cutting Cycle
G94	Motion	End face Turning Cycle
G96	Motion	Constant Surface Speed ON
G97	Motion	Constant Surface Speed Cancel
G98	Motion	Linear Federate per Time
G99	Motion	Federate per Revolution
M00	M-Code	Program Stop (non-optional)
M01	M-Code	Optional Stop: Operator Selected to Enable
M02	M-Code	End of Program
M03	M-Code	Spindle ON (CW Rotation)
M04	M-Code	Spindle ON (CCW Rotation)
M05	M-Code	Spindle Stop
M06	M-Code	Tool Change
M07	M-Code	Mist Coolant ON
M08	M-Code	Flood Coolant ON
M09	M-Code	Coolant OFF
M30	M-Code	End of Program, Rewind and Reset Modes

N - Codes

- Gives an identifying number for each block of information.
- It is generally good practice to increment each block number by 5 or 10 to allow additional blocks to be inserted if future changes are required.

X and Z Codes

- **X and Z** codes are used to specify the coordinate axis.
- Number following the code defines the coordinate at the end of the move relative to an incremental or absolute reference point.

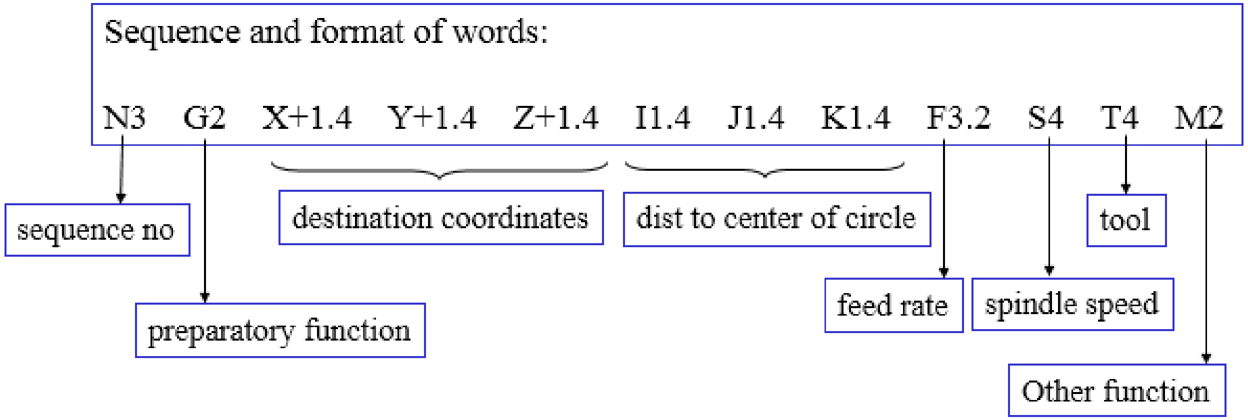
I, J, and K Codes

- I, J, and K codes are used to specify the coordinate axis when defining the center of a circle.
- Number following the code defines the respective coordinate for the center of the circle.

F,S, and T Codes

- F-code: used to specify the feed rate
- S-code: used to specify the spindle speed
- T-code: used to specify the tool identification number associated with the tool to be used in subsequent operations.

A dialogue example for CNC command.



Purpose of using pneumatic / hydraulic pressure and coolant.

Hydraulics:

CNC machine is such type of machine where several jobs are executed in compact area and in less time. In such scenario, hydraulic systems play a big role to execute several functions. Hydraulic Pressure in CNC machine is developed by hydraulic power pack which is a combination of several hydraulic components.

Pascal's law is the basis of hydraulic drive systems. As the pressure in the system is the same, the force that the fluid gives to the surroundings is therefore equal to pressure × area. Here the same principle is used — a small torque can be transmitted into a large force.

Pneumatics:

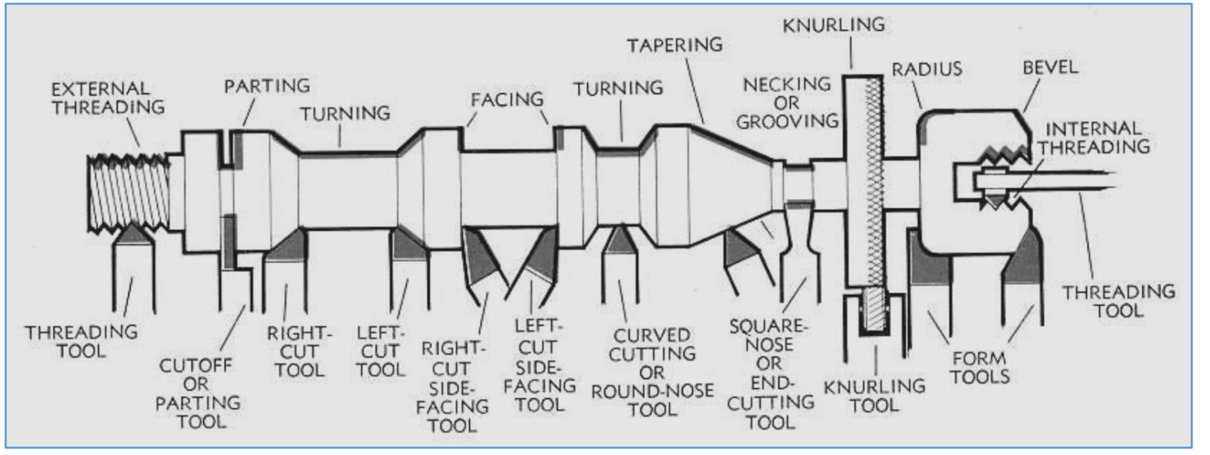
A pneumatic system is a system that uses compressed air to transmit and control energy. Pneumatic systems are used extensively in various industries. Most pneumatic systems rely on a constant supply of compressed air to make them work.

Purpose of using coolant:

The purpose of using CNC coolants and neat oils during the machining process is to cool and lubricate the ferrous or non-ferrous metal being machined and the tool. If the machine coolant fails to control the friction created by deformation, one or both contact surfaces is eroded. This is the start of the failure of the tools within the operation. Besides creating this tenacious film, the micro emulsion or neat oil must exhibit a number of other multi-functional properties, the most important of which are:

- The water soluble coolant or neat oil must be able to withstand the high temperatures and pressures which occur during machining so that friction and wear are minimized.
- The coolant for CNC machines must not be adversely affected by metallic contaminants or tramp oils that can possibly enter a lubrication system.
- The micro emulsion or neat oil must provide effective cooling to remove the heat generated by friction and deformation.
- The coolant for machining should be non-toxic and easy to use.
- It should be readily cleanable with aqueous cleaners or solvent based cleaners.
- The water soluble oil or neat oil should provide rust protection for the work piece and machine tool.

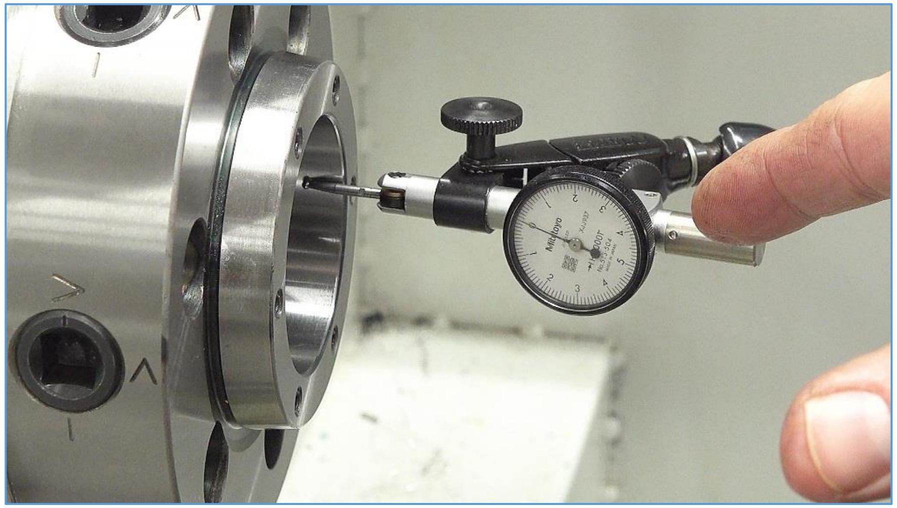
Knowledge of lathe machine tools according to operations.



Lathe tool	Machining process	Shape produced
1. Turning and facing tools	Turning - Facing	Cylinder - Conical - Flat surface
2. Knife or side cutting tool	Turning and facing	Cylindrical shape with perpendicular end shoulder
3. Straight nosed rough cutting tool	Turning - Facing	Rough cylindrical - Rough flat
4. Facing tool	Facing	Flat surface
5. Round nose tool	Turning and facing	Smooth cylindrical - Smooth flat
6. Parting off tool	Parting off	Flat surface
8. Screw cutting tool	External screw cutting	Thread
9. Knurling tool	Knurling	Embossed outside surface

Method of dialing the workpiece.

To center a workpiece having a smooth surface such as round stock, the best method is to use a dial test indicator. Place the point of the indicator against the outside or inside diameter of the workpiece. Revolve the workpiece slowly by hand and notice any deviations on the dial. This method will indicate any inaccuracy of the centering in thousandths of an inch.

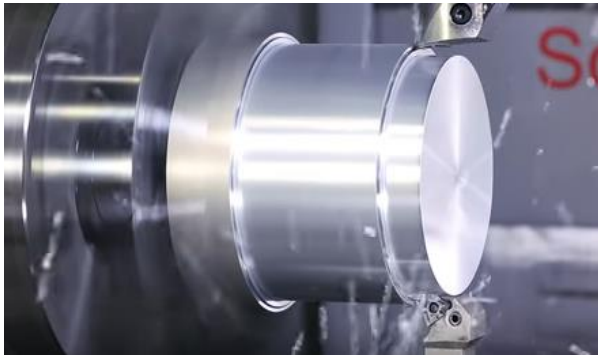


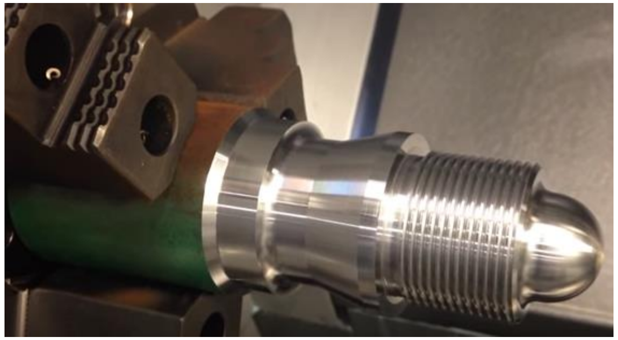
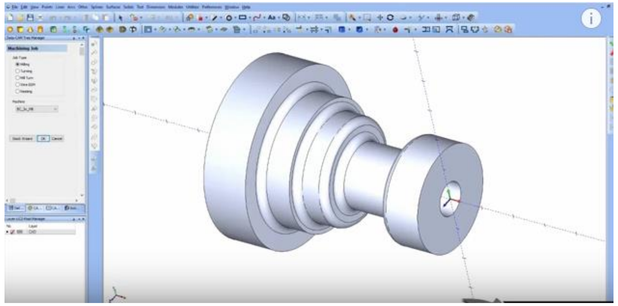
Lathe machine operation sequence:

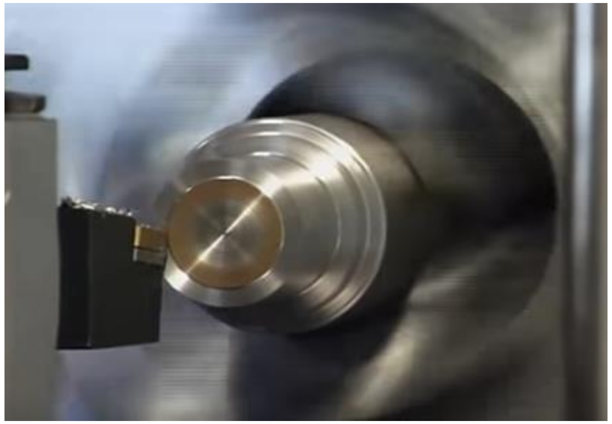
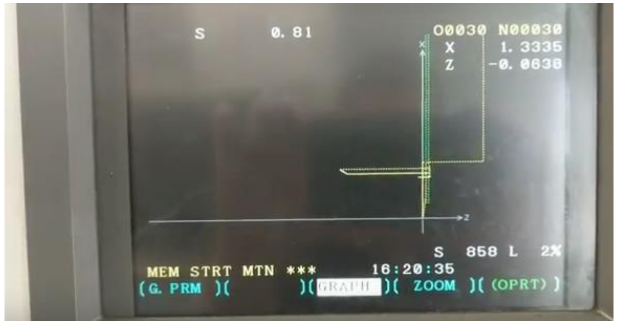
Sequence refers to what operation to complete first and later on?

Before programming on a CNC lathe it is very important to set operational sequence in a logical order, it will not only save the time but helpful to avoid any accident. When setting operational sequence care must be taken to consider it.

Videos:

	Dialing at CNC lathe machine Dialing chuck and Turret Axis on cnc lathe https://www.youtube.com/watch?v=bQkkwztqwWM
	CNC lathe Machine Operation SolidCAM Drehen & Dreh Fräsen https://www.youtube.com/watch?v=JefhHntc6YI
	Basic CNC Programming | CNC Programming for beginners | CNC Programming https://www.youtube.com/watch?v=ZgWYoFWTKJc

	CNC Hand programming final https://www.youtube.com/watch?v=Sid-P8D7U6U
	Reducing CNC Lathe Programming Time With CAD-CAM Software - BobCAD-CAM Webinar Series https://www.youtube.com/watch?v=8Qm1wgXGqss
	CNC lathe setup part 1 https://www.youtube.com/watch?v=fTPluUa6be0

	Cutting Tool Geometries Lathe and Mill SME https://www.youtube.com/watch?v=bbMbFvsRTJo
	Dry run on new CNC lathe. https://www.youtube.com/watch?v=gRiPE6r5LcE

DIES AND MOULDS MAKER

Module-5

LEARNER GUIDE

National Vocational Certificate Level 3

Version 1 - August, 2019

Module 5: 071500973 Perform CNC milling operations

Objective of the module: This competency standard covers the skills and knowledge required to operate CNC milling machine safely

Duration: 200 Hrs **Theory:** 20 Hrs **Practical:** 180 Hrs

Learning Unit	Learning Outcomes	Learning Elements	Materials Required
LU1: **Set Machine programing**	**The trainee will be able to:** Select appropriate programming software Set basic parameters as per specifications Generate program as per given specification Perform post processing of program Select tool size and set offset value as per specification Test run the program Make necessary correction Save the program	CNC milling / VMC applications Major functional parts of CNC milling / VMC machine Knowledge of machine axis traveling concept i.e. right hand rule. Knowledge of tool types and profile G & M code programing concept for milling operations Knowledge of tool path generation according to profile Know the method of performing post processing of program. Know the method of test run the program. Method of editing of program Method to save the program	CNC milling machine Job drawing for milling Computer with CNC programing software.

LU2: **Set tools**	**The trainee will be able to:** Check and verify the pneumatic pressure & coolant Select appropriate tool and clamping device Clamp the tool into tool holder on machine spindle.	Purpose of using pneumatic pressure and coolant. Knowledge of milling machine operations & tools. **Operations:** facing, side milling, pocketing, grooving, contouring, chamfering etc. **Tools:** end mill, shell end mill, face mill, ATC (automatic tool changer), boring bars, removable carbide tips and holders etc.	CNC milling machine / Machining center Milling cutters
LU3: **Set workpiece**	**The trainee will be able to:** Select the appropriate clamping devices according to the job Remove the sharp edges from work piece Perform dialing of workpiece Calculate the offset value of axis Add the offset values in machine parameter Set workpiece zero reference	Dialing and zero setting techniques Method of calculating offset values and setting the values in machine control unit Method of calculating offset values and feeding in machine parameter. Method of setting zero for workpiece Knowledge of touch probe	CNC machine MS plate Hydraulic vice Dial indicator with magnetic stand Center fixture

LU4: **Carryout machining process**	**The trainee will be able to:** Set machine reference point (home position) Ensure proper synchronization between machine control unit and part program file as per standard procedure Control the feed speed and override of machine before operating according to the prescribe procedure Switch machine to execution mode (single block or Auto) as per prescribed method and start machining Compare the block wise movements of machine sequence thoroughly during operation of machine according to the part program.	Know the method of setting of home position Deference between feed speed and override Deference between single block and Auto execution mode. Knowledge of miscellaneous functions	Job drawing Aluminum plate Hydraulic vice Milling cutter Cutting oil Single cut flat file

LU5: **Perform final inspection**	**The trainee will be able to:** Prepare the work piece for inspection Visually Inspect the work piece Manage the required measuring tools Perform the required inspection as per drawing	Knowledge of inspection tools and its use.	Object Inspection tools
LU6: **Demonstrate safe working practice & housekeeping**	**The trainee will be able to:** Select & use appropriate PPEs. Maintain cleanliness at the workplace Ensure relevant safety procedure for CNC milling operations	Health and safety relevant to CNC milling machine shop	CNC machine with all tool and equipment

Examples and illustrations

CNC milling / VMC applications:

For more details please visit: https://academy.titansofcnc.com/files/Fundamentals_of_CNC_Machining.pdf

CNC (Computer Numerical Control) machining refers to a manufacturing process that involves the use computers to control machine parts. CNC machining has been adopted in almost all industries, including small-scale roadside workshops and repair shops.
Everyone involved in manufacturing should take advantage of what this technology can do for their company. For instance, CNC machines:

- Have a high degree of automation that lowers a company's labor intensity.
- Achieve a more precise level of production that produces good product consistency exponentially faster.
- Have multi-axis linkage that allows you to attain complex processing of the prototype machining.

So, what are some of the areas where CNC machining can be applied?

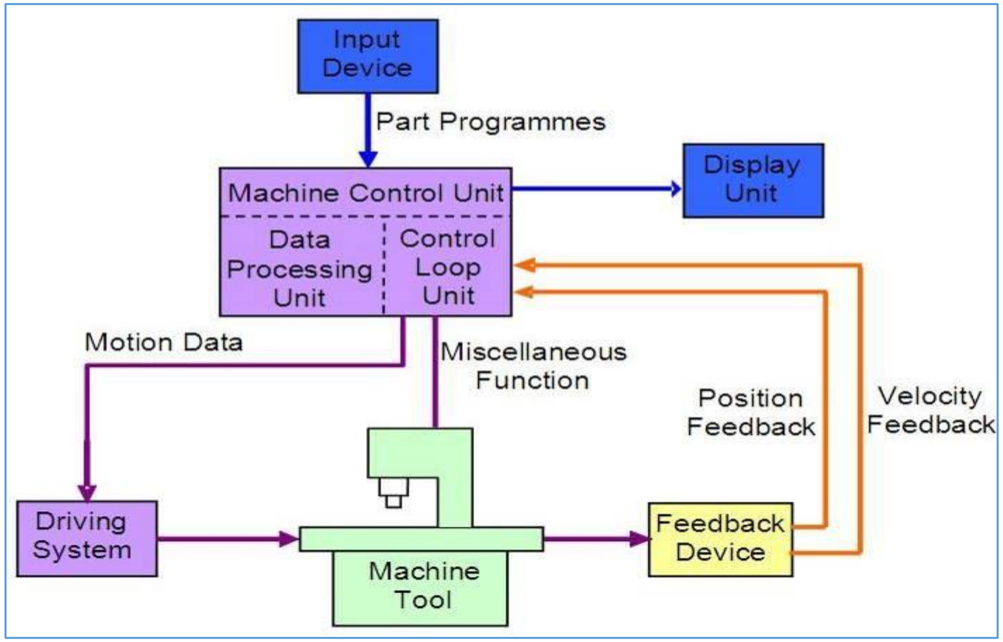
CNC machines are widely used in the metal cutting industry and are best used to produce the following types of product:

- Parts with complicated contours
- Parts requiring close tolerance and/or good repeatability
- Parts requiring expensive jigs and fixtures if produced on conventional machines
- Parts that may have several engineering changes, such as during the development stage of a prototype
- In cases where human errors could be extremely costly
- Parts that are needed in a hurry
- Small batch lots or short production runs

Major functional parts of CNC milling / VMC machine:

A CNC system consists of the following 6 major elements:

1. Input Device
2. Machine Control Unit
3. Machine Tool
4. Driving System
5. Feedback Devices
6. Display Unit



1. **Input devices :**

- Input devices includes:
- Floppy Drive
- USB Flash Drive
- Serial Communication
- Ethernet Communication
- Conversational Programming

2. **Machine Control Unit (MCU)**

The machine control unit is the heart of the CNC system. There are two sub-units in the machine control unit: the Data Processing Unit (DPU) and the Control Loop Unit (CLU).

a. Data Processing Unit

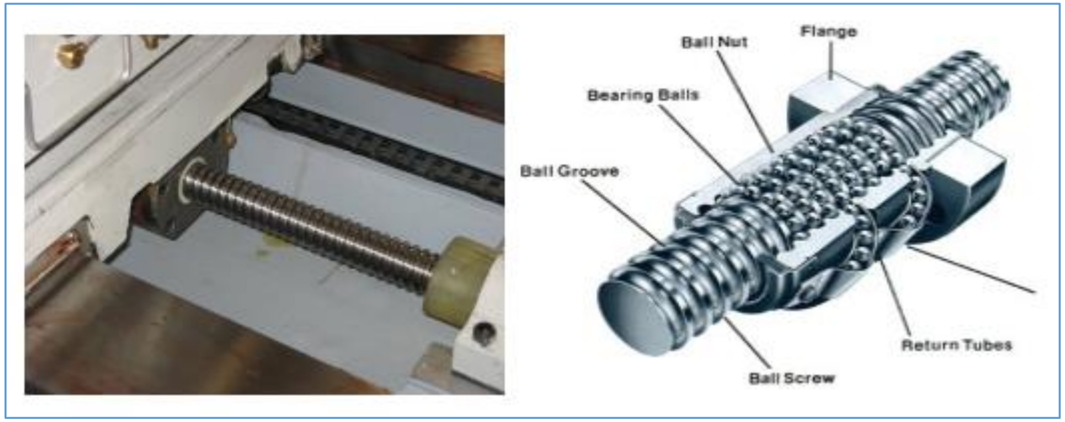
On receiving a part program, the DPU firstly interprets and encodes the part program into internal machine codes. The interpolator of the DPU then calculate the intermediate positions of the motion in terms of BLU (basic length unit) which is the smallest unit length that can be handled by the controller. The calculated data are passed to CLU for further action.

b. Control Loop Unit

The data from the DPU are converted into electrical signals in the CLU to control the driving system to perform the required motions. Other functions such as machine spindle ON/OFF, coolant ON/OFF, tool clamp ON/OFF are also controlled by this unit according to the internal machine codes.

3. Machine Tool

This can be any type of machine tool or equipment. In order to obtain high accuracy and repeatability, the design and make of the machine slide and the driving lead screw of a CNC machine is of vital importance. The slides are usually machined to high accuracy and coated with anti-friction material such as PTFE and Turcite in order to reduce the stick and slip phenomenon. Large diameter recirculating ball screws are employed to eliminate the backlash and lost motion. Other design features such as rigid and heavy machine structure; short machine table overhang, quick change tooling system, etc also contribute to the high accuracy and high repeatability of CNC machines.

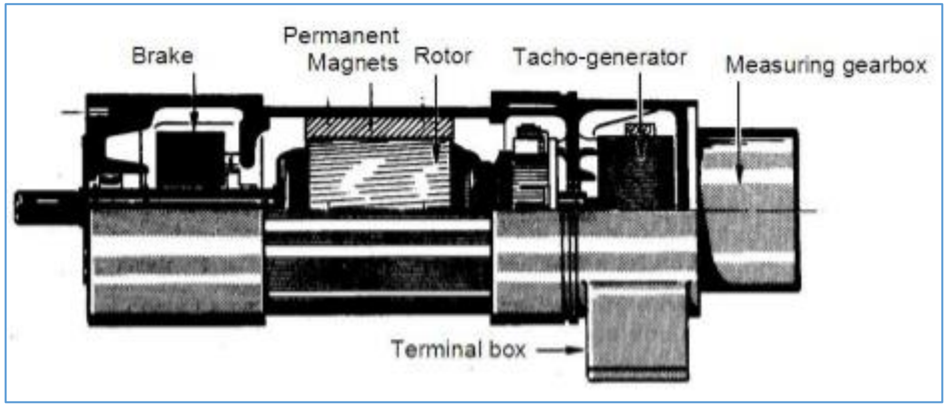


4. Driving System

The driving system is an important component of a CNC machine as the accuracy and repeatability depend very much on the characteristics and performance of the driving system. The requirement is that the driving system has to response accurately according to the programmed instructions. This system usually uses electric motors although hydraulic motors are sometimes used for large machine tools. The motor is coupled either directly or through a gear box to the machine lead screw to moves the machine slide or the spindle. Three types of electrical motors are commonly used.

a. DC Servo Motor

This is the most common type of feed motors used in CNC machines. The principle of operation is based on the rotation of an armature winding in a permanently energized magnetic field. The armature winding is connected to a commutator, which is a cylinder of insulated copper segments mounted on the shaft. DC current is passed to the commutator through carbon brushes, which are connected to the machine terminals. The change of the motor speed is by varying the armature voltage and the control of motor torque is achieved by controlling the motor's armature current. In order to achieve the necessary dynamic behavior it is operated in a closed loop system equipped with sensors to obtain the velocity and position feedback signals.



b. AC Servo Motor

In an AC servomotor, the rotor is a permanent magnet while the stator is equipped with 3-phase windings. The speed of the rotor is equal to the rotational frequency of the magnetic field of the stator, which is regulated by the frequency converter.

AC motors are gradually replacing DC servomotors. The main reason is that there is no commutator or brushes in AC servomotor so that maintenance is virtually not required. Furthermore, AC servos have a smaller power-to-weight ratio and faster response.

c. Stepping Motor

A stepping motor is a device that converts the electrical pulses into discrete mechanical rotational motions of the motor shaft. This is the simplest device that can be applied to CNC machines since it can convert digital data into actual mechanical displacement. It is not necessary to have any analog-to-digital converter nor feedback device for the control system. They are ideally suited to open loop systems.

However, stepping motors are not commonly used in machine tools due to the following drawbacks: slow speed, low torque, low resolution and easy to slip in case of overload. Examples of stepping motor application are the magnetic head of floppy-disc drive and hard disc drive of computer, daisy-wheel type printer, X-Y tape control, and CNC EDM Wire-cut machine.

d. Linear Motor

A linear electric motor is an AC rotary motor laid out flat. The same principle used to produce torque in rotary motors is used to produce force in linear motors. Through the electromagnetic interaction between a coil assembly and a permanent magnet assembly, the electrical energy is converted to linear mechanical energy to generate a linear motion. As the motion of the motor is linear instead of rotational, therefore it is called linear motor.

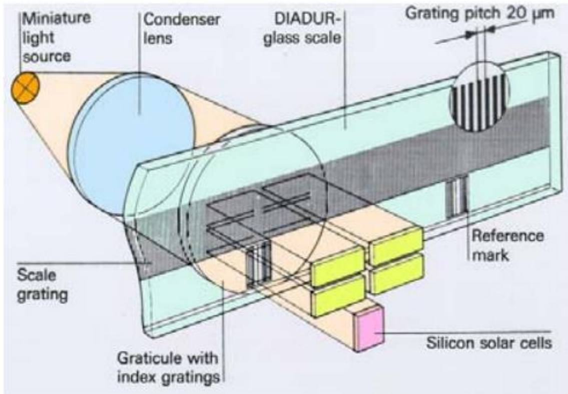
5. Feedback Device

In order to have a CNC machine operating accurately, the positional values and speed of the axes need to be constantly updated. Two types of feedback devices are normally used, positional feedback device and velocity feedback device.

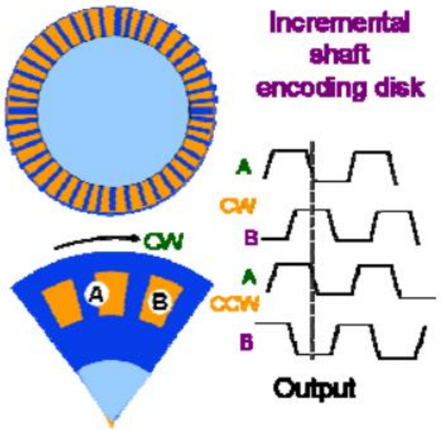
a. Positional Feed Back Devices

There are two types of positional feedback devices: linear transducer for direct positional measurement and rotary encoder for angular or indirect linear measurement.

Linear Transducers - A linear transducer is a device mounted on the machine table to measure the actual displacement of the slide in such a way that backlash of screws; motors, etc. would not cause any error in the feedback data. This device is considered to be of the highest accuracy and also more expensive in comparison with other measuring devices mounted on screws or motors.

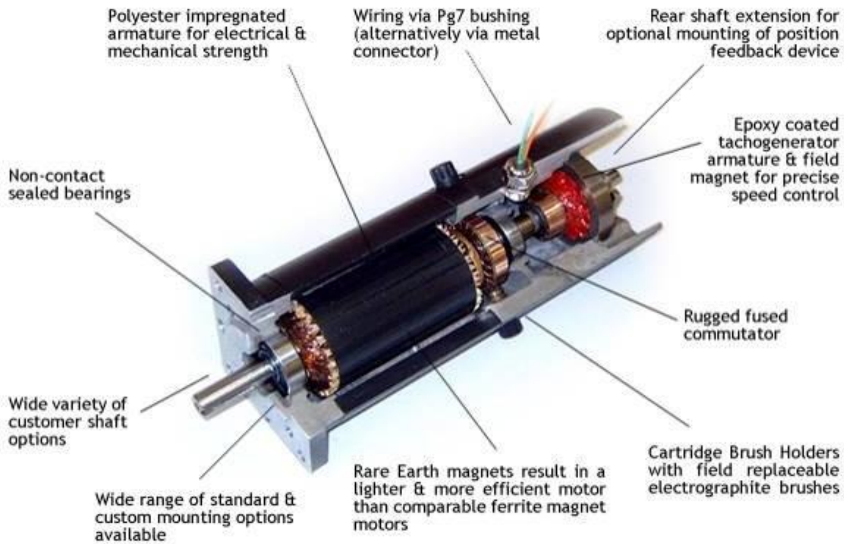


Rotary Encoders - A rotary encoder is a device mounted at the end of the motor shaft or screw to measure the angular displacement. This device cannot measure linear displacement directly so that error may occur due to the backlash of screw and motor etc. Generally, this error can be compensated for by the machine builder in the machine calibration process.



b. Velocity Feedback Device

The actual speed of the motor can be measured in terms of voltage generated from a tachometer mounted at the end of the motor shaft. DC tachometer is essentially a small generator that produces an output voltage proportional to the speed. The voltage generated is compared with the command voltage corresponding to the desired speed. The difference of the voltages can is then used to actuate the motor to eliminate the error.

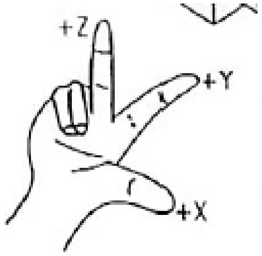


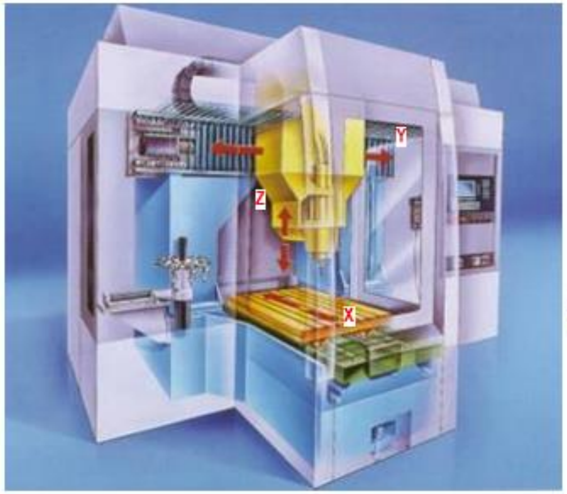
6. Display Unit

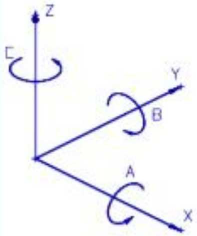
The Display Unit serves as an interactive device between the machine and the operator. When the machine is running, the Display Unit displays the present status such as the position of the machine slide, the spindle RPM, the feed rate, the part programs, etc.
In an advanced CNC machine, the Display Unit can show the graphics simulation of the tool path so that part program can be verified before the actually machining. Much other important information about the CNC system can also displayed for maintenance and installation work such as machine parameters, logic diagram of the programmer controller, error messages and diagnostic data.

Knowledge of machine axis traveling concept i.e. right hand rule.

The Cartesian coordinate system consists of three number lines, labeled X, Y and Z, set at 90 degree angles to each other as shown in Figure below. The origin, or Datum, is where the three axes cross each other. The labels, orientations, and directions of the Cartesian coordinate system in Figure are typical of most Vertical and Horizontal Machining Center (VMC & HMC).







Knowledge of tool types and profile

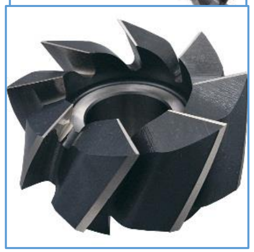
For more details please visit: https://academy.titansofcnc.com/files/Fundamentals_of_CNC_Machining.pdf

The tool use in milling machine are called “cutter”. They have a cylindrical body rotates on its own axis and is provided equally space teeth with engage them. Compare with lathe cutting tool it is engage a very short time during rotation. This result longer a tool life. This may be HSS, or solid Carbide or Carbide tipped. The helix may be right hand or left hand.

End mill cutter: A shank type cutter has teeth on the circumferential surface and one end. This type of cutter used for facing, profiling, and end milling. These are available in two or more flutes. Smaller end mills are having straight shank and large end mills have taper shank, also these kind of cutters can use horizontally or vertically both.

Shell end mill cutter:

The shell end mill has not only peripheral cutting edges, but also cutting edges on one face. Consequently, it is used to manufacture plain and orthogonally offset surfaces.



Face milling cutter:

Face milling is used to generate plane surfaces. In face milling, sometime cutter heads tipped with inserted cemented carbide tips are used at present. A general rule of thumb holds that face milling takes priority over peripheral milling. Shell end mill cutters are also use as face milling operation.

Dovetail cutter:

Dovetail cutters are used to make dovetail slots in a metal, for producing dovetail slides first make straight slot and then use this cutter for producing dovetail slot.

Woodruff key cutter:

Keyways are grooves of different shapes cut along the axis of the cylindrical surface of shafts, into which keys are fitted to provide a positive method of locating and driving members on the shafts. The most commonly used types of keys are the Woodruff key, the square-ends machine key, and the round-end machine key.

G & M code programing concept for milling operations:

For more details please visit: https://academy.titansofcnc.com/files/Fundamentals_of_CNC_Machining.pdf

A CNC program consists of blocks, words and addresses.

Block

A command given to the control unit is called a block.

Words

A block is composed of one or more words. A word is composed of an identification letter and a series of numerals, e.g. the command for a feed rate of 200mm/min is F200.

Address

The identification letter at the beginning of each word is called address. The meaning of the address is in accordance with EIA (Electronic Industries Association) standard RS-274-D. The most common 'addresses' are listed below:

Sequence number	N
Preparatory function	G
Co-ordinate word	X, Y, Z
Parameters for Circular Interpolation	I, J, K
Feed function	F
Spindle function	S
Tool function	T
Miscellaneous function	M

An example of a program is as follows: N20 G01 X20.5 F200 S1000 M03
N21 G02 X30.0 Y40.0 I20.5 J32.0

Sequence Number (N Address)

A sequence number is used to identify the block. It is always placed at the beginning of the block and can be regarded as the name of the block. The sequence numbers need not be consecutive. The execution sequence of the program is according to the actual sequence of the block and not the sequence of the number. In fact some CNC systems do not require sequence numbers.

Preparatory Function (G Address):

A preparatory function determines how the tool is to move to the programmed target. The most common G addresses are listed below:

Code	Function
G00	Point to point position at rapid feed

G01 Linear interpolation
G02 Circular interpolation, clockwise
G03 Circular interpolation, anti clockwise
G40 Cutter compensation cancel
G41 Cutter compensation, Left
G42 Cutter compensation, Right
G45 - G48 Other cutter compensation, if used G70 - G79 Milling and turning cycle
G80 - G89 Drilling and tapping cycle G90 Absolute dimensioning
G91 Incremental dimensioning

Co-ordinate Word (X/Y/Z Address)

A co-ordinate word specifies the target point of the tool movement (absolute dimension system) or the distance to be moved (incremental dimension). The word is composed of the address of the axis to be moved and the value and direction of the movement.

Example: X100 Y-200

Represents the movement to (100, 200). Whether the dimensions are absolute or incremental will have to be defined previously (using G90 or G91).

Parameter for Circular Interpolation (I/J/K Address)

These parameters specify the distance measured from the start point of the arc to the center. Numerals following I, J and K are the X, Y and Z components of the distance respectively.

Spindle Function (S Address)

The spindle speed is commanded under an S address and is always in revolution per minute. It can be calculated by the following formula:

$$\text{Spindle Speed} = \frac{\text{Surface Cutting Speed (m/min)} \times 1000}{\pi \times \text{Cutter Diameter (mm)}}$$

The following table gives the surface cutting speeds for some common materials:

Cutting tool Material	**Workpiece material**			
	Al alloy	**Brass**	**Cast Iron**	**Mild Steel**
HSS	**120**	**75**	**18**	**30**
Carbide	**500**	**180**	**120**	**200**

Example: S2000 represents a spindle speed of 2000rpm

Feed Function (F Address)

The feed is programmed under an F address except for rapid traverse. The unit may be in mm per minute (in the case of milling machine) or in mm per revolution (in the case of turning machine). The unit of the feed rate has to be defined at the beginning of the program. The feed rate can be calculated by the following formula:

Feed Rate = Chip Load / tooth X No of Tooth X Spindle Speed

The following table gives the chip load per tooth of milling cutters cutting some common materials:

Milling Cutter Material	**Chip load per tooth (mm/rev)**			
	Al alloy	**Brass**	**Cast Iron**	**Mild Steel**
HSS	**0.28**	**0.18**	**0.20**	**0.13**
Sintered Carbide	**0.25**	**0.15**	**0.25**	**0.25**

Example: F200 represents a feed rate of 200mm/min

Tool Function (T Address)

The selection of tool is commanded under a T address. ***Example:*** T02 represents tool number 2

Miscellaneous Function (M Address)

The miscellaneous function is programmed to control the machine operation other than for co-ordinate movement. The most common M functions are as follows:

Code	Function
M00	Program stop
M03	Spindle rotation clockwise
M04	Spindle rotation counterclockwise
M05	Spindle STOP
M06	Change of Tool
M08	Coolant ON
M09	Coolant OFF
M10	Clamp
M11	Unclamp
M30	Program end and ready for another start

Steps for CNC Programming and Machining

The following is the procedures to be followed in CNC programming and machining. The most important point is to verify the program by test run it on the machine before the actual machining in order to ensure that the program is free of mistakes.

a. Study the part drawing carefully.
b. Unless the drawing dimensions are CNC adapted, select a suitable program zero point on the work piece. The tool will be adjusted to this zero point during the machine set up.
c. Determine the machining operations and their sequence.
d. Determine the method of work clamping (vice, rotary table, fixtures etc).

e. Select cutting tools and determine spindle speeds and feeds.

f. Write program (translate machining steps into program blocks). If many solutions are possible, try the simplest solution first. It is usually longer, but better to proceed in this way.

g. Prepare tool chart or diagram, measure tool geometry (lengths, radii) and note.

h. Clamp work piece and set up machine.

i. Enter compensation value if necessary.

j. Check and test program. It is a good practice to dry run the program (i) without the workpiece, (ii) without the cutting tools, or (iii) by raising the tool to a safe height.

If necessary, correct and edit program and check again.

k. Start machining.

Knowledge of tool path generation according to profile

After the geometric modeling, machining data such as the job setup, operation setup and motion definition are input into the computer to produce the cutting location file (CL file) for machining the workpiece.

a. Job setup

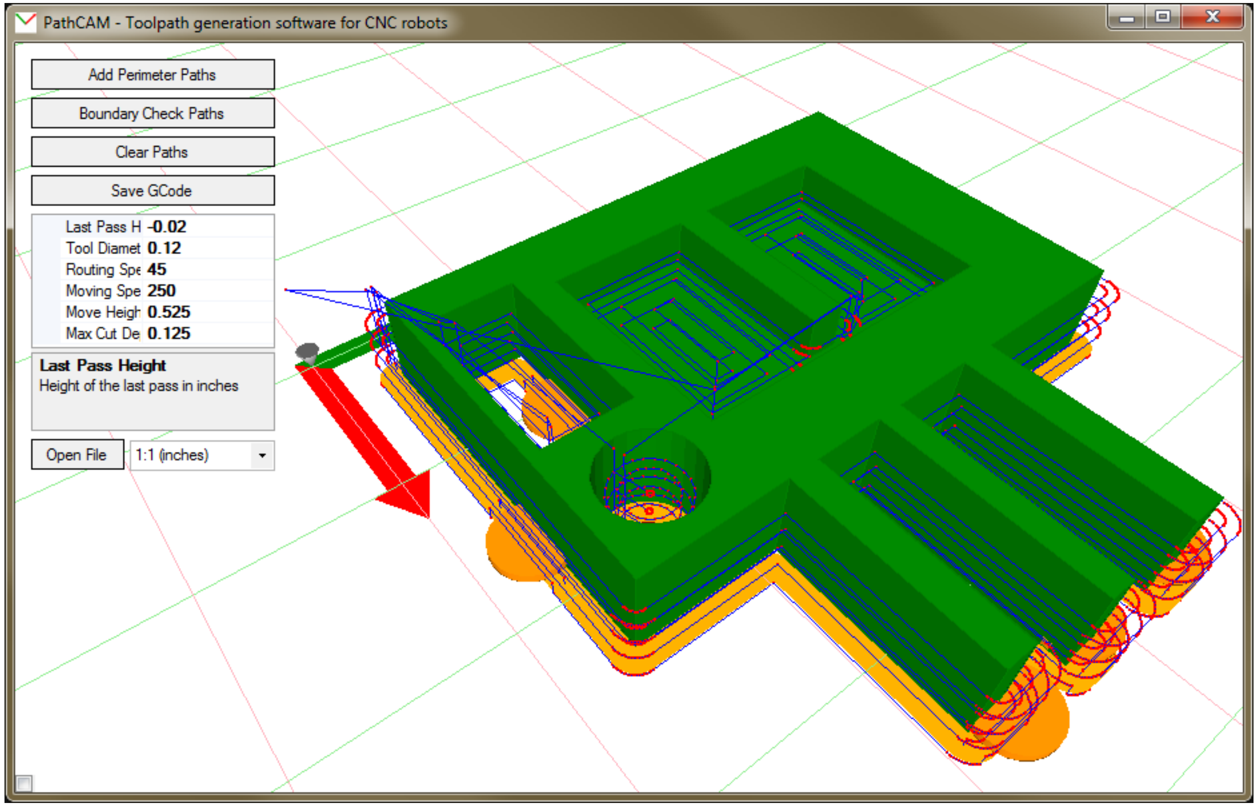
This is to input the machine datum, home position, and the cutter diameters for the CL file.

b. Operation setup

This is to input into the system the operation parameters such as the feed rate, tolerance, and approach / retract planes, spindle speed, coolant ON/OFF, stock offset and the tool selection etc.

c. Motion definition

Built in machining commands are used to control the tool motion to machine the products. This includes the hole processing, profile machining, pocketing, surface machining, gouge checking, etc.



Know the method of performing post processing of program.

Post Processing

Different CNC machines have different features and capabilities, the format of the CNC program may also vary from each other. A process is required to change the general instructions from the cutter location file to a specific format for a particular machine tool and this process is called post processing.

Post processor is a computer software which converts the cutter location data files into a format which the machine controller can interpret correctly. Generally, there are two types of post processor.

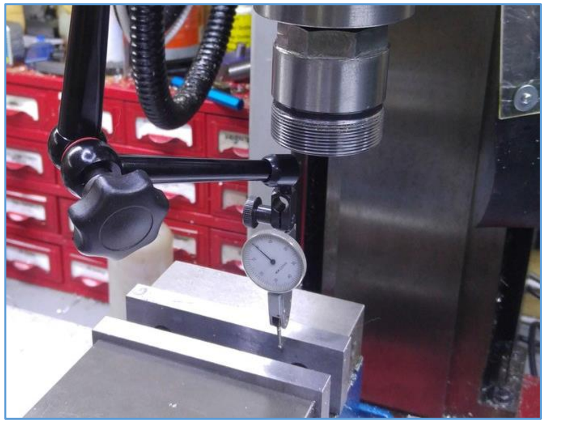
a. Specific Post Processor:

This is a tailor-made software which output the precise code for a specific CNC machine. The user is not required to change anything in the program.

b. Generic (Universal) Post Processor:

This is a set of generalized rules which needs the user to customize into the format that satisfies the requirements of a specific CNC machine.

Dialing and zero setting techniques:



Considerable attention must be given to proper positioned determination (work piece bearing and support surfaces) in order to attain the required angularity of the end faces to the longitudinal sides of the work pieces.

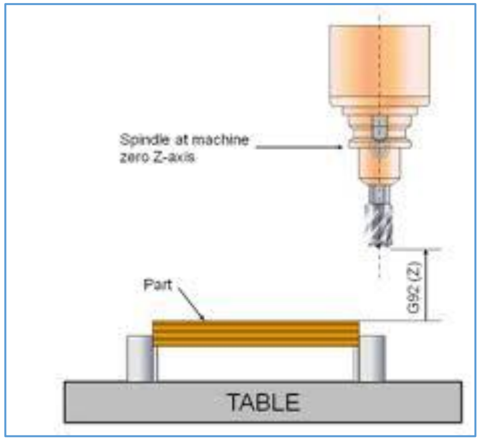
Whenever using a mill one must always remember to square the vice. Additionally you must remember to square the head. The goal of squaring the vice is so that one may run an indicator from one side of the jaw to the other without the indicator moving. Try to maintain right angle of the needle of indicator from the surface. Using a parallel that has been clamped on the vice is also a popular method as it gives you an indication of the movement of the part compared to the movement of the machine table.

Zero Setting:

Come to the setting up machine, although every CNC Milling machine set-up procedure is slightly different, but here are explained these generic steps which cnc machinists practice on a daily basis for a 3 axis vertical CNC Milling machine.

1. Clean Surface: Clean all surfaces like table, vise jaws and part (work piece) with cloth, so that no oil drops, material chips remain there.
2. Load Tool: Load tools required to complete part (including edge finder, vise leveling at 0 degree).
3. **Load Part**: Load part (work piece) in vise or hold your part (work piece) with your machine holding arrangements.

4. **X,Y axis's Offsetting**: Set the part (work piece) offset. For this purpose you may use edge finder or you can do it with your End Mill Cutter (if you are using end mill cutter for tool offset, then read Tool Offset Article). First do the zero offset for the X axis. Pick up the X0 position by using edge finder. Go to the zero offset page and add the machine absolute X value to the value currently in the zero offset page's registry. Do the same for the Y axis.
5. **Z axis Offsetting**: After X,Y axis's offsetting set the tool length offset for each tool by loading first tool in spindle. Manually move the Z axis down until the tool's tip is near the Z0 position. Get a piece of 1.00 mm shim stock (always use any fix size of shim like 1 mm, 2 mm or 5 mm) and hold it between the part (work piece) and the tip of the tool. Carefully lower the Z axis in 0.001 mm increments until the shim stock can be pulled with a slight drag. Go to your tool length offset page and enter the machine's absolute Z value plus -1.00 mm in the tools registry. Repeat procedure to additional tools. Note: -1.00 mm is added for the shim stock's thickness.
6. **Cutter Radius Compensation**: Enter each tool diameter in tool length offset page. That will be helpful when you are using Cutter Radius Compensation in your program.



Note: Now a day's sensor based touch probes are intensively used for setting workpiece axis.

Knowledge of touch probe

Probing is an established best practice for maximizing the efficiency, quality, capability and accuracy of machine tools. Standard routines built into modern CNC controls simplify the integration of probing cycles into machining operations and offline tools. These routines, combined with a CAD interface, make the simulation of measurement functions easy.

Touch probes are designed for use on machine tools, particularly milling machines and machining centers. Touch probes help reduce setup times, increase machine usage time, and improve the dimensional accuracy of the finished workpiece. Setup, measuring, and monitoring functions can be performed manually or—in conjunction with most CNC controls—can be controlled by a program.

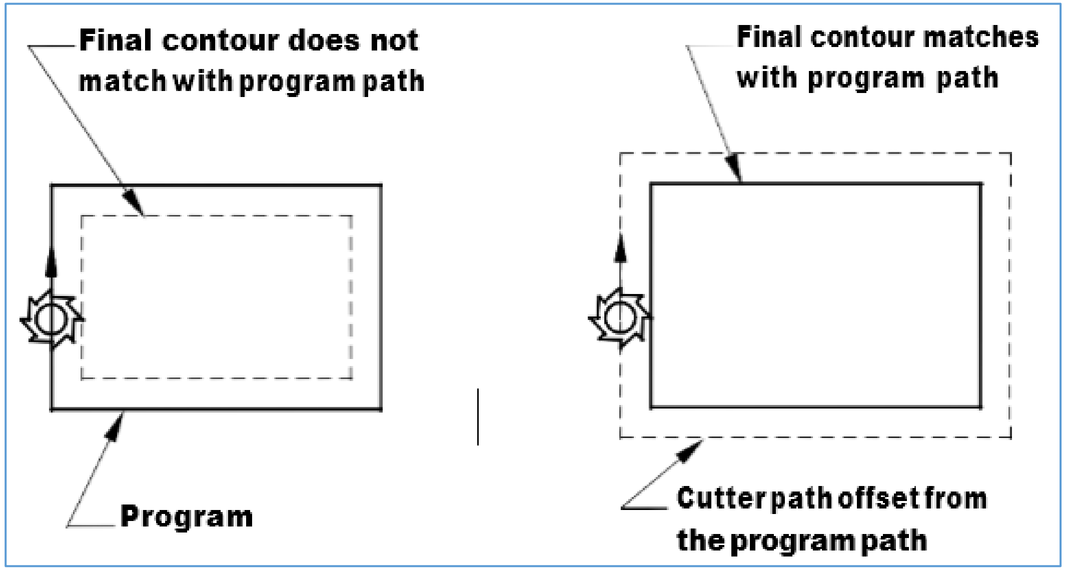
Touch probes have a whole series of technologically convincing features, such as the contact-free optical sensors, the integrated blower/flusher jets for cleaning the measuring point, or the large deflection path with a rated break point in the stylus.

Method of calculating offset values and setting the values in machine control unit.

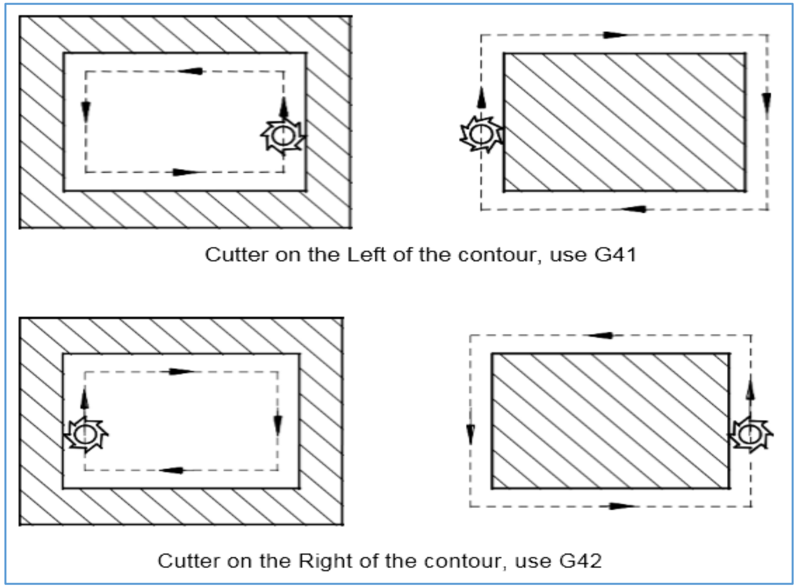
Cutter Compensation (G40/G41/G42)

In CNC machining, if the cutter axis is moving along the programmed path, the dimension of the workpiece obtained will be incorrect since the diameter of the cutter has not be taken into account.

Modern CNC systems are capable of doing this type of calculation which is known as cutter compensation. What the system requires are the programmed path, the cutter diameter and the position of the cutter with reference to the contour. Normally, the cutter diameter is not included in the program. It has to be input to the CNC system in the tool setting process.



If the cutter is on the left of the contour, G41 is used. If the cutter is on the right of the contour, G42 will be used. G40 is to cancel the



compensation calculation.

Know the method of setting of home position

You are operating a CNC machine sometimes in auto mode and other times in **jog mode**. But all the time the values which a CNC operator sees time to time regularly are the CNC machine current position. While the CNC machine is running in auto mode the current-axis-position values will regularly change. And while in jog mode you move CNC machine axis you see the current axis values are changing.

- So these CNC machine current position values are very critical.
- And these current position values are regularly updated if CNC machine axis are moved

Now you note the current values on a paper, and turn-off the CNC machine. Now turn-on the CNC machine, now again take the current axis position values, the values have changed, why?

When your CNC machine is switched-on, it has no provision to know the current axis position.

So at this time the CNC machine needs a way to tell CNC machine control where it is.

So better that we tell the CNC machine where it is now, it is much better to take the CNC machine axis to a specified and fixed point whose values are known, and now tell CNC machine the current position.

All the above work is automatically done when we take the CNC machine to reference point or we zero return the CNC machine.

The reference point is a fixed point inside the CNC machine whose values are already stored in the CNC machine. So when we take the CNC machine to the reference point those values automatically get active and the CNC machine comes to know its current axis position.

If you want to go deeper then, there are limit switches for every axis in CNC machine to tell the reference point position. So when we take the CNC machine to the reference point those limit switches got active and tell the CNC machine control that the specified axis is reaching to its reference point position, so the CNC control update the current position for that specific axis because CNC control already knows the position at that point, and this is repeated with all the CNC machine axis.

Fanuc G28 G Code for CNC Zero Return

You can make a call in MDI mode on a CNC machine with fanuc CNC control.

Deference between feed and speed override.

For one reason or other you want to increase or decrease the speed or feed of the CNC machine **for some time**, you definitely have a way to just alter the CNC machine program, but there is one more suitable solution the Feed Override and Speed Override Controls. The feed override and speed override are the most suitable and handy way to control the CNC machine feed and speed through CNC control panel.

You control the speed and feed in percentage. When the feed override is 100% the actually feed which is programmed will be active. But if the feed override is 50% then the feed will decrease by that ratio, now the machine tools will run with 50% of feed. So if you have programmed 0.5 mm/rev feed then with 100% the 0.5 will be active, but for 50% feed override the actually tool feed will be 0.25 mm/rev.

The same rule applies for speed override, for 100% the actual programmed speed will be active and spindle will revolve with the actual programmed speed but at 50% speed override the spindle speed will drop by 50%.

Feed Override Speed Override Minimum / Maximum Values

Normally you can control speed override and feed override from 0% to 120%. At 0% speed override the spindle will stop rotating, and at 0% feed override the tool will stop working (the tool will be stationary).

No doubt 120% feed override and speed override is just **safe**. But some CNC machines give even more flexibility. Normal CNC machine has just 0% to 120% feed override and speed override.

Deference between single block and Auto execution mode.

For more details please visit: https://academy.titansofcnc.com/files/Fundamentals_of_CNC_Machining.pdf

Every CNC machine has couple of Modes or call it Standard Working Modes, such as Auto Mode, Single Block Mode, MDI (Manual Data Input) and Jog Mode and there will be more Modes but those mostly will be CNC machine or CNC control specific modes.

Let’s know actually what these CNC Modes are and what they do.

CNC Machine Single Block Mode

The CNC program consists of CNC program blocks. The CNC program blocks are numbered such as N10, N20, and N30 and so on. In CNC machine single block mode when you press the cycle start button on the CNC machine control panel only one block of the CNC program will be executed and the machine slide or CNC machine carriage will stop or you might say that the CNC machine cutting tool feed will be at hold but remember that this does not mean that CNC machine fully stops, only CNC machine axis movement will be at hold and all the other functions like coolant will continue to flow and the spindle will continue to rotate. In short the CNC machine single block mode will not affect the machine spindle rotation but it will only hold the tool feed after the CNC program block is executed. And if you press the cycle start button again the next program block of the CNC program will be executed and the machine will again be at hold after that block completion.

CNC Machine Auto Mode or Automatic Mode

You will rarely see a production shop CNC machine out of CNC machine auto mode. The most used mode on a CNC machine (on some controls like Sinumerik 840D the machine control panel has a setting key which when switched off the machine will only be in auto mode and you can’t change the modes). In CNC machine auto mode when you press the cycle start button on the machine control panel the whole CNC program will be executed. To run the CNC machine in auto mode there are some conditions on some CNC machine such as the CNC machine safety guard door must be closed.

CNC Machine Jog Mode

CNC machine Jog mode is one of the most used CNC mode. Jog mode is mostly used to travel the CNC machine carriage (or CNC machine Slide) such as CNC machine’s axis movement e.g. x-axis z-axis. These axis movement can be via axis specific keys or through the CNC machine hand wheel.

CNC Machine MDI Mode or MDA Mode

The CNC machine MDI (Manual Data Input) mode or MDA (Manual Data Automatic) mode can be called a semi-automatic mode. The CNC MDI or MDA mode is mostly used to index tools, or to execute one block of CNC code (on some models of CNC such as sinumerik 840D you can execute multi block CNC program in MDA mode). The CNC M-Codes can be executed in MDI or MDA mode. You can even rotate the CNC machine spindle to a specific RPM in MDI or MDA mode.

Knowledge of miscellaneous functions:

For more details please visit: https://academy.titansofcnc.com/files/Fundamentals_of_CNC_Machining.pdf

Modern CNC systems have some specially designed functions to simplify the manual programming. However, since most of these functions are system oriented, it is not intended to discuss them here in detail. The following paragraphs give a brief description of commonly used functions in modern CNC systems. The user should refer to the programming manuals of the machine for the detail programming and operation.

a. **Mirror Image**

This is the function that converts the programmed path to its mirror image, which is identical in dimensions but geometrically opposite about one or two axes.

b. **Program Repetition and Looping**

In actual machining, it is not always possible to machine to the final dimension in one go. This function enables the looping of a portion of the program so that the portion can be executed repeatedly.

c. **Pocketing Cycle**

Pocketing is a common process in machining. This is to excavate the material within a boundary normally in zigzag path and layer by layer. In a pocketing cycle, the pattern of cutting is pre-determined. The user is required to input parameters including the length, width and depth of the pocket, tool path spacing, and layer depth. The CNC system will then automatically work out the tool path.

d. **Drilling, Boring, Reaming and Tapping Cycle**

This is similar to pocketing cycle. In this function, the drilling pattern is pre-determined by the CNC system. What the user has to do is to input the required parameters such as the total depth of the hole, the down feed depth, the relief height and the dwell time at the bottom of the hole.

Health and safety relevant to CNC milling machine shop:

For more details please visit: https://academy.titansofcnc.com/files/Fundamentals_of_CNC_Machining.pdf

Safety tips for operating a CNC machine.

CNC machines, regardless of how big or small they might be, are still machines.

They consist of sharp and hard pieces that could easily injure someone if use inappropriately. Using a CNC machine could be dangerous if you did not use the machine properly.

In order to protect yourself and the people around you, it's important to understand how to operate CNC machines safely.

A lot of CNC safety precautions apply when you are using any form of machinery. For instance, you should always be wearing protective glasses when operating your CNC machine. You should also be using hearing protection while using a CNC machine as well. Even if you are experienced, these simple safety measures can protect you from short-term and long-term injuries.

In order to keep others safe, it is important that you are cleaning up after yourself after you use the CNC machine.

Whether you have a home workshop or you are working in a crowded space, it is vital that you clean up scraps of materials from the floor and surrounding area. Someone could easily fall on a scrap piece of wood or slip on sawdust: prevent accidents by simply cleaning messes when you leave.

You also should be keeping a safe distance between yourself and the bit at all times.

Leaving six inches of space will allow you to be close enough to work but far enough away to prevent your hand or your body from getting injured by being too close.
Although this tip might be considered common sense, you should never leave the room while operating a CNC machine.

Although machines can operate alone, you should always be within sight of the machine in case an issue surfaced.

The Importance of cleaning in CNC machining.

When it comes to your CNC machines, you probably know the ins and outs of operation, but have you ever looked into their cleaning? Many individuals forget the importance of regular cleaning or get swept up in the excitement of everyday work, allowing this task to fall to the wayside. We at CNC Masters would like to bring cleaning back to the forefront of your attention for a minute, reminding you of just how important it is to clean all components of your CNC machines on a regular (we recommend weekly) basis. Why? We have listed a few of the most important reasons below.

Longevity:

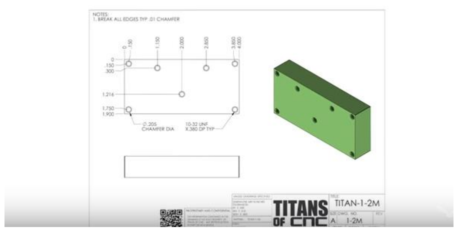
Your machines are used to cut through some tough materials, and because of this, they are going to experience a lot of everyday wear and tear. Just think of how much of a mess the metal shavings, cutting fluids and oils can make of your shop floor! Regular cleaning is just one way to help extend the lifetime of your machines. Prevent grit and grime from building up both on their exteriors and interiors to help ensure longevity.

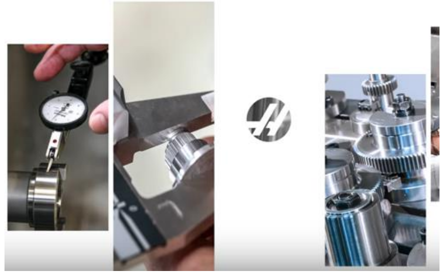
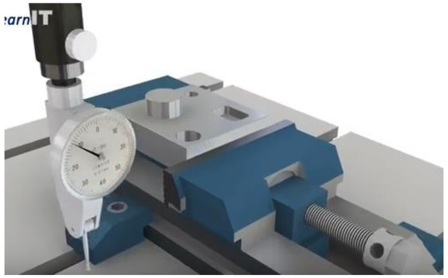
Functionality:

Clean machining parts will give you the best possible results, helping to ensure that the products you make are the best that they can be. Regular cleaning will also allow you to check machining components often, helping to ensure you notice parts that need replacing or adjusting – instead of finding out when your machine breaks down.

Safety:

A clean machining shop is a safe one, and this motto should apply to your machines themselves, as well as the tools and surfaces around them. Weekly cleaning will keep your fleet of CNC machines in top shape, preventing potential injuries and break downs.

	G & M Code - Titan Teaches Manual Programming on a CNC Machine. https://www.youtube.com/watch?v=5XihF05K4yM
	CNC Mill Tutorial https://www.youtube.com/watch?v=dFDOZcznm68
	How to: Set Tool Length and Work Offsets https://www.youtube.com/watch?v=uNjMIIRttFE

	How to Square and Indicate a Vise on Your CNC Mill https://www.youtube.com/watch?v=cn05fX55pqc
	Dial Test Indicator - Hole Center https://www.youtube.com/watch?v=7_yscOLOFS4

DIES AND MOULDS MAKER

Module-6

LEARNER GUIDE

National Vocational Certificate Level 3

Version 1 - August, 2019

Module 6: 071400974 Perform Heat Treatment

Objective of the module: This module covers the knowledge, skills and understanding needed to perform heat treatment through standard procedures

Duration: 80 Hrs **Theory:** 10 Hrs **Practical:** 70 Hrs

Learning Unit	Learning Outcomes	Learning Elements	Materials Required
LU1: **Prepare material for heat treatment**	**The trainee will be able to:** Debur the work piece before heat treatment. Prepare provision of holding the work piece before putting in furnace. Set the wok piece according to the furnace/ torch available.	Knowledge of Heat treatment process steps i.e. debur, wiring, furnace temperature, use of charcoal, socking time, quenching etc. Knowledge of workpiece holding method before and after putting into furnace. Knowledge of setting work piece into furnace.	Heat treatment furnace Carbon steel block Steel wire Charcoal Plier Steel tray
LU2: **Perform stress relieving**	**The trainee will be able to:** Set the temperature of furnace as per material requirement. Place the work piece in furnace. Set furnace off time according to the stress relieving requirement Take out the workpiece from the furnace after	Introduction to heat treatment processes. **Process:** stress relieving, annealing, hardening, tempering and normalizing. Understanding Iron carbon diagram for setting temperature according to material composition Setting soaking time on furnace Method of handling workpiece after heating in a furnace	Machined steel block Steel wire Charcoal Steel tray furnace

	giving required soaking time		
LU3: **Perform hardening**	**The trainee will be able to:** Set the temperature of furnace as per material specification Ensure part is well prepared and cleaned Ensure that quenching media is at room temperature Move quenching media to proximity of furnace. (If required to reduce heat loss of a part.) Ensure the part is heated to the specified temperature and held in the furnace to reach the soaking time Submerge the part in specific quenching media (bath) to achieve required hardness	Know the required hardening temperature as per material specifications Know the method of preparing workpiece for hardening Knowledge of quenching media and its temperature for a heat treatment process Time Temperature Transformation (TTT) Diagram Different types of quenching media and their effects. **Types:** water, oil. Brine etc. **Effects:** cracks, stresses etc. Know the method of calculating soaking time. Know the method of quenching Know the method of testing hardness. **Method:** Rockwell (A,B,C scale), Vickers, brinell. etc	Carbon steel block Furnace Steel wire Charcoal Steel tray Quenching media Tong

	Verify that the required hardness is achieved		
LU4: **Perform Tempering**	**The trainee will be able to:** Set the temperature of furnace as per required hardness Ensure part is heated to a set temperature according to tempering specification to reach specified condition Repeat the procedure for second & third time where required Allow the workpiece to cool at room temperature Verify that the required hardness is achieved	Mechanical properties of steels. **Properties**: ductility, malleability, hardness, tempering, elasticity, plasticity, brittleness, toughness etc. Know the temperature range for tempering. Know the soaking time for tempering. Cooling rate effects on a heated parts i.e. slow cooling and fast cooling. Know the method of testing tempered hardness.	Carbon steel block Tempering Furnace Steel wire Steel tray Tempering bath Tong Set Wire cutter Plier Flat file
LU5: **Perform annealing**	**The trainee will be able to:** Set the temperature of furnace as per material specification	Knowledge of Stress, strain diagram. Know the annealing temperature as per material composition Method of preparing a workpiece for annealing. Knowledge of calculating of soaking time for annealing Method of cooling and effects of cooling rate on material	Carbon steel block Furnace Steel wire Charcoal Steel tray

	Ensure part is well prepared and cleaned from oil prior heating Ensure part is heated to a set temperature according to annealing specification to reach specified condition Control cool down rate according to material specification following the annealing procedure Verify that the required hardness is achieved	Grain structures fully annealed and hardened material.	Quenching media
LU6: **Perform final Inspection**	**The trainee will be able to:** Prepare workpiece for inspection Perform visual inspection for scratches, cracks, craters, geometric deformation & distortion Select & use the tools and equipment such as hardness tester, chart, indenter and V-block	Knowledge of preparing heat treated workpiece for inspection Knowledge of defects associated with heat treatment. i.e cracks, geometric deformation and distortion etc. Knowledge of hardness testing tools i.e. hardness tester, conversion charts, indenters etc. Calibration of a hardness tester machine Hardness testing methods. **Method:** Rockwell (A, B, C scale), Vickers, brinell. etc	Hardened steel piece Hardness tester Calibration block Diamond tip 120 degree

	Verify hardness tester is functioning properly by using standard calibration samples Set up work piece on hardness tester by aligning with indenter activate mechanism to initiate hardness test Compare test value against standard specification Record the value for quality assurance		
LU7: **Demonstrate safe working practice & housekeeping**	**The trainee will be able to:** Select & use appropriate PPEs. Maintain cleanliness at the workplace Ensure relevant safety procedure for Heat treatment operations	Use of PPEs • Flame retardant Apron • Face Mask • Long Sleeve Leather Gloves • Safety Shoes Safe Procedures for Heat Treatment Cleanliness requirement for heat treat work place	Flame retardant Apron Face Mask Long Sleeve Leather Gloves Safety Shoes

Examples and illustrations:

Knowledge of Heat treatment process steps:

For more details please visit: https://www.uddeholm.com/files/heattreatment-english.pdf

All heat-treating processes are similar because they all involve the heating and cooling of metals. However, there are differences in the methods used, such as the heating temperatures, cooling rates, and quenching media necessary to achieve the desired properties.

The heat treatment of ferrous metals (metals with iron) usually consists of annealing, normalizing, hardening, and/or tempering.

Most nonferrous metals can be annealed, but never tempered, normalized, or *case hardened*.

To successfully heat treat a metal, you need to have the proper equipment with close control over all factors relevant to the heating and cooling. For example, the furnace must be the proper size and type with the temperatures controlled and kept within the prescribed limits for each operation, and you must have the appropriate quenching media to cool the metal at the correct rate.

The furnace atmosphere itself affects the condition of the metal being heat treated. This atmosphere consists of the gases in the furnace's heating chamber that circulate and surround the metal being heated.

STAGES of HEAT TREATMENT

You accomplish heat treatment in three major stages:

Stage I — Heat the metal slowly to ensure a uniform temperature.

Stage 2 — Soak (hold) the metal at a given temperature for a given time.

Stage 3 — Cool the metal to room temperature.

Heating Stage:

In the heating stage, the primary objective is to heat uniformly, and you attain and maintain uniform temperatures by slow heating. If you heat unevenly, one section can expand faster than another, resulting in a distorted or cracked part.

The appropriate heating rate will depend on several factors.

- The metal's heat conductivity. A metal with a high-heat conductivity heats at a faster rate than one with a low conductivity.
- The metal's condition. The heating rate for hardened (stressed) tools and parts should be slower than the heating rate for

unstressed or untreated metals.

- A metal part's size and cross section. To prevent warping or cracking, you need to heat large cross-sectioned parts slowly to allow the interior temperature to remain close to the surface temperature. Parts with uneven cross sections will naturally tend to heat unevenly, but they are less apt to crack or excessively warp when you keep the heating rate slow.

Soaking Stage:

In the soaking stage, the objective is to hold the metal to the proper temperature until the desired internal structural changes take place. "Soaking period" is the term you use for the time the metal is held at the proper temperature. The chemical analysis of the metal and the mass of the part will determine the appropriate soaking period. (Note: For steel parts with uneven cross sections, the largest section determines the soaking period.)

Except for the rare variance, you should not bring the temperature of a metal directly from room temperature to soaking temperature in one operation. Instead, heat the metal slowly to a temperature just below the point at which the internal change occurs and hold it at that temperature until you have equalized the heat throughout. Following this process (called "preheating"), quickly heat the metal to its final required temperature.

When a part has an intricate design, you may have to preheat it to more than one temperature stage to prevent cracking and excessive warping. For example, assume an intricate part needs to be heated to 1500°F for hardening.

You may need to heat this part slowly to a 600°F stage and soak it at this temperature for a defined period, then heat it slowly and soak it at a 1200°F stage, and then heat it quickly to the hardening temperature of 1500°F.

NOTE

Nonferrous metals seldom require preheating; in fact, preheating can cause an increase in their grain size.

Cooling Stage:

In the cooling stage, the objective is self-explanatory, but there are different processes to return a metal to room temperature, depending on the type of metal.

To cool the metal and attain the desired properties, you may need to place it in direct contact with a cooling medium (a gas, liquid, solid, or a combination), and any cooling rate will depend on the metal itself and the chosen medium. Therefore, the choice of a cooling medium has an important influence on the properties desired.

Cooling metal rapidly in air, oil, water, brine, or some other medium is called quenching.

Quenching is usually associated with hardening since most metals that are hardened are cooled rapidly during the process. However, neither quenching nor rapid cooling always results in increased hardness. For example, a water quench is usually used to anneal copper, and some other metals are cooled at a relatively slow rate for hardening, such as air-hardened steels.

Some metals crack or warp during quenching, while others suffer no ill effects; so the quenching medium must fit the metal. Use brine or water for metals that require a rapid cooling rate; use oil mixtures for metals that need a slower cooling rate. Generally, you should water-harden carbon steels, oil-harden alloy steels, and quench nonferrous metals in water.

Introduction to heat treatment processes.

Process: stress relieving, annealing, hardening, tempering and normalizing.

For more details please visit: https://www.asminternational.org/documents/10192/23555666/ASM+Subject+Guide_HeatTreating.pdf

Stress relieving:

Stress Relieving is the treatment of a metal or alloy by heating to a predetermined temperature below its lower transformation temperature followed by cooling in air. The primary purpose is to relieve stresses that have been absorbed by the metal from processes such as forming, straightening, machining or rolling.

Annealing:

Annealing is a process involving heating and cooling, usually applied to produce softening. The term also refers to treatments intended to alter mechanical or physical properties, produce a definite microstructure, or remove gases. The temperature of the operation and the rate of cooling depend upon the material being annealed and the purpose of the treatment.

Hardening:

A ferrous metal is normally hardened by heating the metal to the required temperature and then cooling it rapidly by plunging the hot metal into a quenching medium, such as oil, water, or brine. Most steels must be cooled rapidly to harden them. The hardening process increases the hardness and strength of metal, but also increases its brittleness.

Tempering:

Steel is usually harder than necessary and too brittle for practical use after being hardened. Severe internal stresses are set up during the rapid cooling of the metal. Steel is tempered after being hardened to relieve the internal stresses and reduce its brittleness. Tempering consists of heating the metal to a specified temperature and then permitting the metal to cool. The rate of cooling usually has no effect on the metal structure during tempering. Therefore, the metal is usually permitted to cool in still air. Temperatures used for tempering are normally much lower than the hardening temperatures. The higher the tempering temperature used, the softer the metal becomes. High-speed steel is one of the few metals that becomes harder instead of softer after it is tempered.

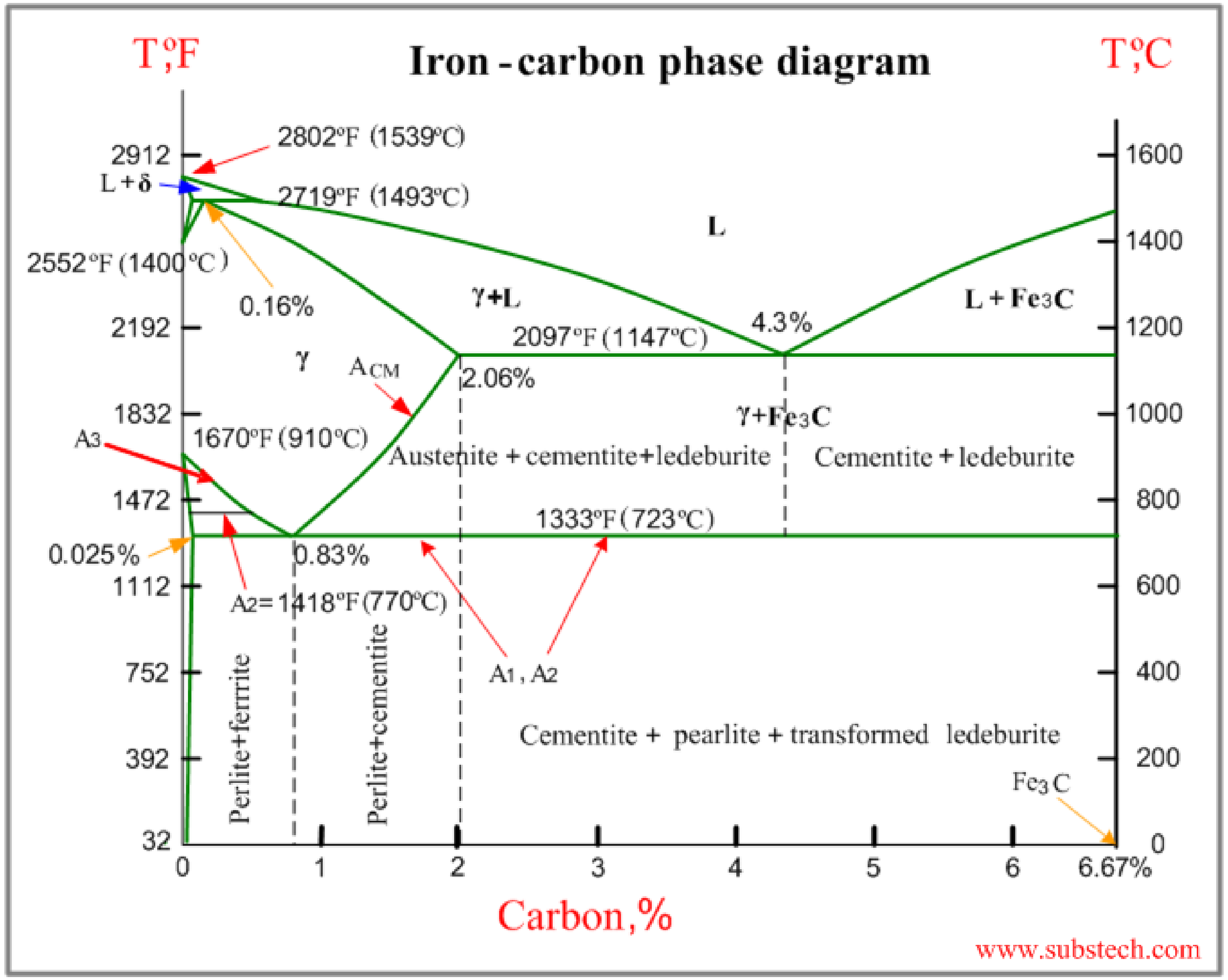
Normalizing:

Ferrous metals are normalized to relieve the internal stresses produced by machining, forging, or welding. Normalized steels are harder and stronger than annealed steels. Steel is much tougher in the normalized condition than in any other condition. Parts that will be subjected to impact and parts that require maximum toughness and resistance to external stresses are usually normalized. Normalizing prior to hardening is beneficial in obtaining the desired hardness, provided the hardening operation is performed correctly. Low carbon steels do not usually require normalizing, but no harmful effects result if these steels are normalized. Normalizing is achieved by heating the metal to a specified temperature (which is higher than either the hardening or annealing temperatures), soaking the metal until it is uniformly heated, and cooling it in still air.

Understanding Iron carbon diagram for setting temperature according to material composition:

For more details please visit: https://www.substech.com/dokuwiki/doku.php?id=iron-carbon_phase_diagram

Iron-carbon phase diagram describes the iron-carbon system of alloys containing up to 6.67% of carbon, discloses the phases compositions and their transformations occurring with the alloys during their cooling or heating.
Carbon content 6.67% corresponds to the fixed composition of the iron carbide Fe_3C.
The diagram is presented in the picture:



The following phases are involved in the transformation, occurring with iron-carbon alloys:

- **L** - Liquid solution of carbon in iron;
- **δ-ferrite** – Solid solution of carbon in iron.

Maximum concentration of carbon in δ-ferrite is 0.09% at 2719 ºF (1493ºC) – temperature of the peritectic transformation.
The crystal structure of δ-ferrite is BCC (cubic body centered).

- **Austenite** – interstitial solid solution of carbon in γ-iron.

Austenite has FCC (cubic face centered) crystal structure, permitting high solubility of carbon – up to 2.06% at 2097 ºF (1147 ºC).
Austenite does not exist below 1333 ºF (723ºC) and maximum carbon concentration at this temperature is 0.83%.

- **α-ferrite** – solid solution of carbon in α-iron.α-ferrite has BCC crystal structure and low solubility of carbon – up to 0.025% at 1333 ºF (723ºC). α-ferrite exists at room temperature.

- **Cementite** – iron carbide, intermetallic compound, having fixed composition Fe_3C.

Cementite is a hard and brittle substance, influencing on the properties of steels and cast irons.
The following phase transformations occur with iron-carbon alloys:

Alloys, containing up to 0.51% of carbon, start solidification with formation of crystals of δ-ferrite. Carbon content in δ-ferrite increases up to 0.09% in course solidification, and at 2719 ºF (1493ºC) remaining liquid phase and δ-ferrite perform peritectic transformation, resulting in formation of austenite.
Alloys, containing carbon more than 0.51%, but less than 2.06%, form primary austenite crystals in the beginning of solidification and when the temperature reaches the curve ACM primary cementite stars to form.

Iron-carbon alloys, containing up to 2.06% of carbon, are called **steels**.
Alloys, containing from 2.06 to 6.67% of carbon, experience eutectic transformation at 2097 ºF (1147 ºC). The eutectic concentration of carbon is 4.3%.
In practice only hypoeutectic alloys are used. These alloys (carbon content from 2.06% to 4.3%) are called **cast irons**. When temperature of an alloy from this range reaches 2097 ºF (1147 ºC), it contains primary austenite crystals and some amount of the liquid phase. The latter decomposes by eutectic mechanism to a fine mixture of austenite and cementite, called **ledeburite**.
All iron-carbon alloys (steels and cast irons) experience eutectoid transformation at 1333 ºF (723ºC). The eutectoid concentration of carbon is 0.83%.
When the temperature of an alloy reaches 1333 ºF (733ºC), austenite transforms to pearlite (fine ferrite-cementite structure, forming as a result of decomposition of austenite at slow cooling conditions).

Critical temperatures

- **Upper critical temperature (point) A_3** is the temperature, below which ferrite starts to form as a result of ejection from austenite in the hypoeutectoid alloys.

- **Upper critical temperature (point) A_{CM}** is the temperature, below which cementite starts to form as a result of ejection from austenite in the hypereutectoid alloys.
- **Lower critical temperature (point) A_1** is the temperature of the austenite-to-pearlite eutectoid transformation. Below this temperature austenite does not exist.
- **Magnetic transformation temperature A_2** is the temperature below which α-ferrite is ferromagnetic.

Phase compositions of the iron-carbon alloys at room temperature

- **Hypoeutectoid steels** (carbon content from 0 to 0.83%) consist of primary (proeutectoid) ferrite (according to the curve A3) and pearlite.
- **Eutectoid steel** (carbon content 0.83%) entirely consists of pearlite.
- **Hypereutectoid steels** (carbon content from 0.83 to 2.06%) consist of primary (proeutectoid) cementite (according to the curve A_{CM}) and pearlite.
- **Cast irons** (carbon content from 2.06% to 4.3%) consist of proeutectoid cementite C_2 ejected from austenite according to the curve A_{CM} , pearlite and transformed ledeburite (ledeburite in which austenite transformed to pearlite).

Time Temperature Transformation (TTT) Diagram:

TTT diagram gives

1- Nature and type of transformation.
2- Rate of transformation.
3- Stability of phases under isothermal transformation conditions.
4- Temperature or time required to start or finish transformation .
5- Qualitative information about size scale of product .
6- Hardness of transformed products

Factors affecting TTT diagram:

1- Composition of steel-
   (a) Carbon wt%,
   (b) Alloying element wt%

2- Grain size of austenite

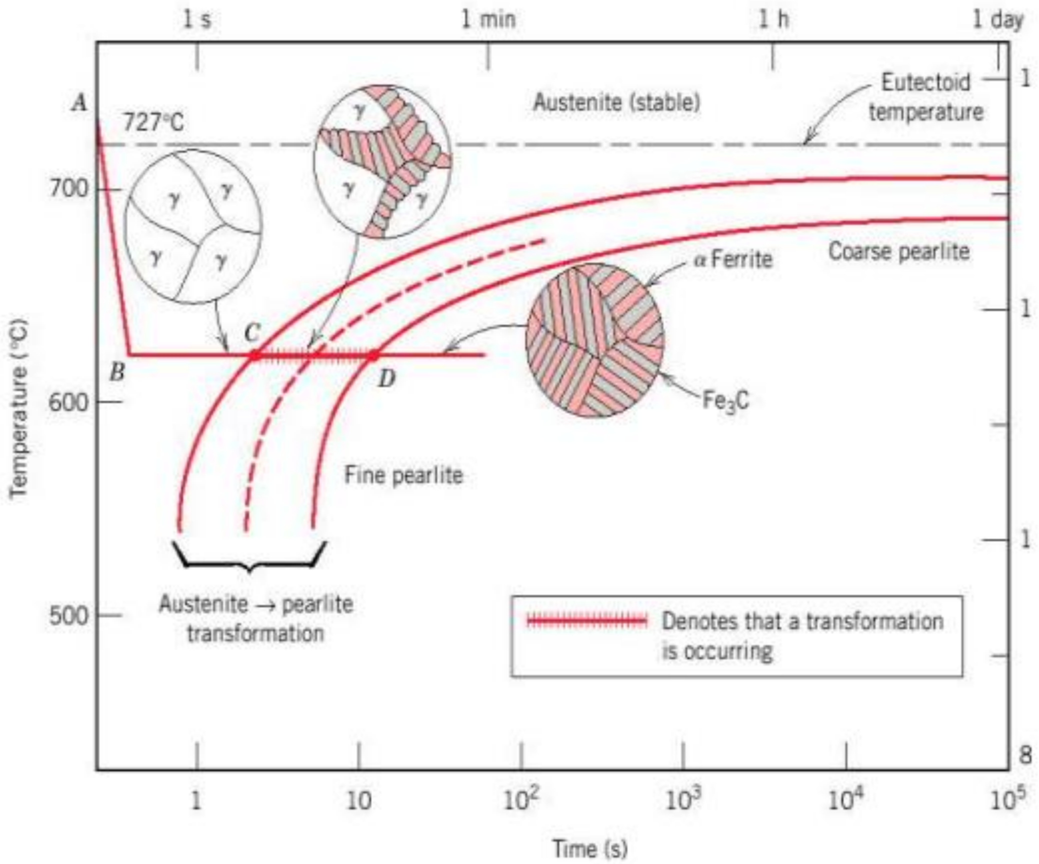
3- Heterogeneity of austenite.

The time-temperature transformation curves correspond to the start and finish of transformations which extend into the range of temperatures where austenite transforms to pearlite.

- Above 550 C, austenite transforms completely to pearlite.
- Below 550 C, both pearlite and bainite are formed.
- Below 450 C, only bainite is formed.

From The below fig:

- The horizontal line C-D that runs between the two curves marks the beginning and end of isothermal transformations.
- The dashed line curves that represents the time to transform half the austenite to pearlite.



N**OTES:**

- The thickness of the ferrite and cementite layers in pearlite phase is ~ 8:1.
- The absolute layer thickness depends on the temperature of the transformation.
- The higher the temperature, the thicker the layers.

Different types of quenching media and their effects.

For more details please visit: http://www.tpub.com/steelworker1/12.htm

Quenching metal is one of the critical stages in the heat treatment of a metal part because it's during that process that added hardness is locked in.

The concept is relatively simple: Heat a metal and then rapidly cool it to make it harder. But in terms of the chemistry involved, the process is complex and trade-offs abound as metallurgists must decide which quenching medium and method will achieve the specified qualities.

Severity of quench:

The severity of a quench refers to how quickly heat can be drawn out of a part. Different quenching media have different degrees of severity.

Caustics are the most severe quenchants, followed by oils, then salts and, finally, gases.

The makeup of metal parts and the specified hardness to be achieved dictate which quenching medium is used. Generally, low-hardenability parts made from carbon steel and low-alloy steel require more severe quenches to achieve a specified hardness. High-alloy steels, which are much more harden able, are best quenched in less severe media.

Caustics:

The most severe quenches are executed with water, brines and caustic sodas. While these quenchants can pull heat out of parts more quickly than other quenching media, faster isn't always better.

Quenching in caustics dissipates heat so quickly that metal parts are at risk of cracking and warping due to the drastic variation in temperature between the part surface and its core. In addition, workers must take special precautions when using caustic materials because they're harmful when inhaled or exposed to skin and eyes.

Oils:

Quenching metal in oil is the most popular method because it is relatively severe but with a diminished risk of cracking and warping. In addition, a wide range of parts quench well in oils because the chemical makeup and temperature of a quenching oil can be adjusted to suit desired end results.

For example, if a metallurgist determines a part's intended final properties require faster quenching to achieve, "fast" oils are used. These oils are formulated to extend the amount of time during which the highest rate of cooling takes place. Quenching in fast oils is best suited for low-carbon steels and low-alloy parts. As the method's name indicates, these quenches do not take long.

Conversely, sometimes cooling needs to be slowed. Hot oils—which are kept at higher temperatures—cool metal surfaces, but not so quickly that a part's core temperature and surface temperature differ too widely. High-alloy parts with intricate designs quench well in hot oils, as the method reduces the risk of warping and **cracking associated with** differences in surface and core temperatures. Quenching in hot oil is a slower process compared to quenching in fast oil.

Because oil is flammable, workers must know the flashpoint of the oil in use as well as the load weight and surface area of the products in the workload to avoid fires during quenching.

Molten salt

Quenching metal parts in molten salt (also called salt baths) comes with a further reduced risk of distortion or cracking of parts because they're hotter than hot oils. This means cooling is more controlled and uniform compared to colder, faster and more severe quenches.

The hotter the quenchants, the less severe the quench. The less severe the quench, the lower the risk of distortion.

Different mixtures of salts have different melting points and working ranges, offering added versatility as a quenching option. Because salts are not flammable, they pose no risk of fire.

On the other end of the spectrum, some salt mixtures have high melting points and working ranges and can be used to heat parts.

Salt baths are a long-lasting heat treating and quenching solution as long as they're properly maintained. This includes ensuring oxides are regularly removed from high-heat salts and sledging out high-heat salts that contaminate quench salts on salt-to-salt lines.

Gas:

Quenching metal via gas in vacuum furnaces has become more popular for parts that require high hardness and specific finishes with significantly reduced risk of distortion.

In gas quenching, parts are sealed in a vacuum chamber before being blasted with gases. The rate of cooling of a part can be precisely controlled by adjusting the pressure and speed at which the gas is delivered. Additionally, due to the fact that gas quenches occur in vacuum chambers, parts emerge significantly cleaner compared to other quenching media.
Nitrogen is the most popular gas quenchant due to its relatively low atomic mass, wide availability and low cost. Helium and argon are also used in gas quenching. Specified finished qualities dictate which gas quenchants are to be used.
High-alloy tool steels and jet engine turbines are common examples of parts often quenched in gas.

Defects in Heat Treatment of Steels:
Defects formed in steels during heat treatment are listed below.

Decarburization:
Heating of metals for long periods at high temperature in oxidizing atmosphere causes the loss of carbon from the surface. Heating in protective atmosphere can decrease this effect.

Oxidization:
Oxidation will result in a thick layer of scale formed on the surface of the article. This also be avoided by using inert atmosphere.

Quenching cracks:
Quenching cracks occurs when cooling rate is more than critical rate. It is avoided by tempering immediately and avoiding sharp corners.

Warping:
Warping is produced by non-uniform heating.

Overheating:
Heating long period at high temperature produces coarse grain microstructure, resulting in the loss of duality and impact strength. It can be prevented by annealing and normalizing.

Soft spots:
Soft spots appear due to localized decarburization, bubble formation and in-homogeneity of initial structure. It can be avoided by effective quenching.

Excessive or insufficient hardens after tempering:
It is due to insufficient or excessive holding time while tempering produces this defect. A proper tempering temp and holding time or subsequent annealing can prevent this defect.

Know the method of testing hardness.

For more details please visit: https://www.asminternational.org/documents/10192/1849770/06671g-ch.pdf

Rockwell test method:

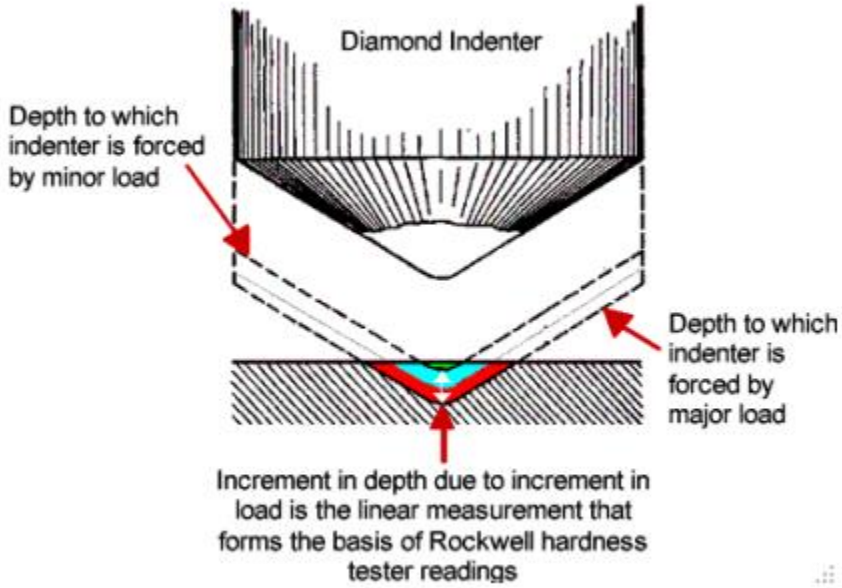
Rockwell Scales Rockwell hardness values are expressed as a combination of a hardness number and a scale symbol representing the indenter and the minor and major loads. The hardness number is expressed by the symbol HR and the scale designation.

There are 30 different scales. The majority of applications are covered by the Rockwell C and B scales for testing steel, brass, and other metals. However, the increasing use of materials other than steel and brass as well as thin materials necessitates a basic knowledge of the factors that must be considered in choosing the correct scale to ensure an accurate Rockwell test. The choice is not only between the regular hardness test and superficial hardness test, with three different major loads for each, but also between the diamond indenter and the 1/16, 1/8, 1/4 and 1/2 in. diameter steel ball indenters.

For soft materials such as copper alloys, soft steel, and aluminum alloys a 1/16" diameter steel ball is used with a 100-kilogram load and the hardness is read on the "B" scale. In testing harder materials, hard cast iron and many steel alloys, a 120 degrees diamond cone is used with up to a 150 kilogram load and the hardness is read on the "C" scale. There are several Rockwell scales other than the "B" & "C" scales, (which are called the common scales). A properly reported Rockwell value will have the hardness number followed by "HR" (Hardness Rockwell) and the scale letter. For example, 50 HRB indicates that the material has a hardness reading of 50 on the B scale.

Principe of the Rockwell Test:

1. The indenter moves down into position on the part surface
2. A minor load is applied and a zero reference position is established
3. The major load is applied for a specified time period (dwell time) beyond zero
4. The major load is released leaving the minor load applied



Brinell Test Method:

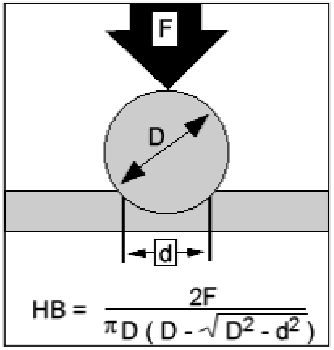
All Brinell tests use a carbide ball indenter. The test procedure is as follows:

• The indenter is pressed into the sample by an accurately controlled test force.

• The force is maintained for a specific dwell time, normally 10 - 15 seconds.

• After the dwell time is complete, the indenter is removed leaving a round indent in the sample. • The size of the indent is determined optically by measuring two diagonals of the round indent using either a portable microscope or one that is integrated with the load application device.

• The Brinell hardness number is a function of the test force divided by the curved surface area of the indent. The indentation is considered to be spherical with a radius equal to half the diameter of the ball. The average of the two diagonals is used in the following formula to calculate the Brinell hardness.



where:
HB = the Brinell hardness number
F = the imposed load in kg
D = the diameter of the spherical indenter in mm
d = diameter of the resulting indenter impression in mm

The Brinell number, which normally ranges from HB 50 to HB 750 for metals, will increase as the sample gets harder. Tables are available to make the calculation simple.

Vickers hardness test method:

The Vickers **hardness test method** consists of indenting the **test material** with a diamond indenter, in the form of a right pyramid with a square base and an angle of 136 degrees between opposite faces subjected to a load of 1 to 100 kgf. The full load is normally applied for 10 to 15 seconds.

Mechanical properties of steels.

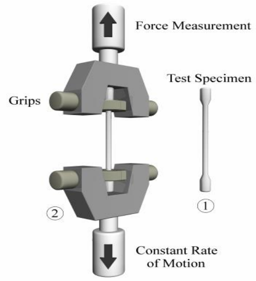
Properties: ductility, malleability, hardness, tempering, elasticity, plasticity, brittleness, toughness etc.

For more details please visit: http://uhv.cheme.cmu.edu/procedures/machining/ch2.pdf

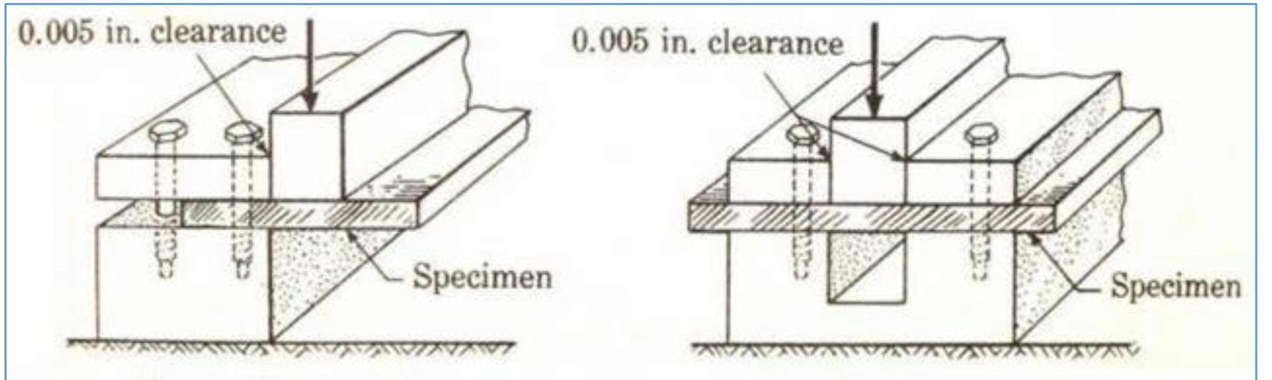
The internal reactions of a metal known as mechanical properties. The to external forces are mechanical properties are directly related to each other. A change in one property usually causes a change in one or more additional properties.
For example, if the hardness of a metal is increased, the brittleness usually increases and the toughness usually decreases. Following is a brief explanation of the mechanical properties and how they relate to each other.

TENSILE STRENGTH

Tensile strength is the ability of a metal to resist being pulled apart by opposing forces acting in a straight line. It is expressed as the number of pounds of force required to pull apart a bar of the material 1 inch wide and 1 inch thick.

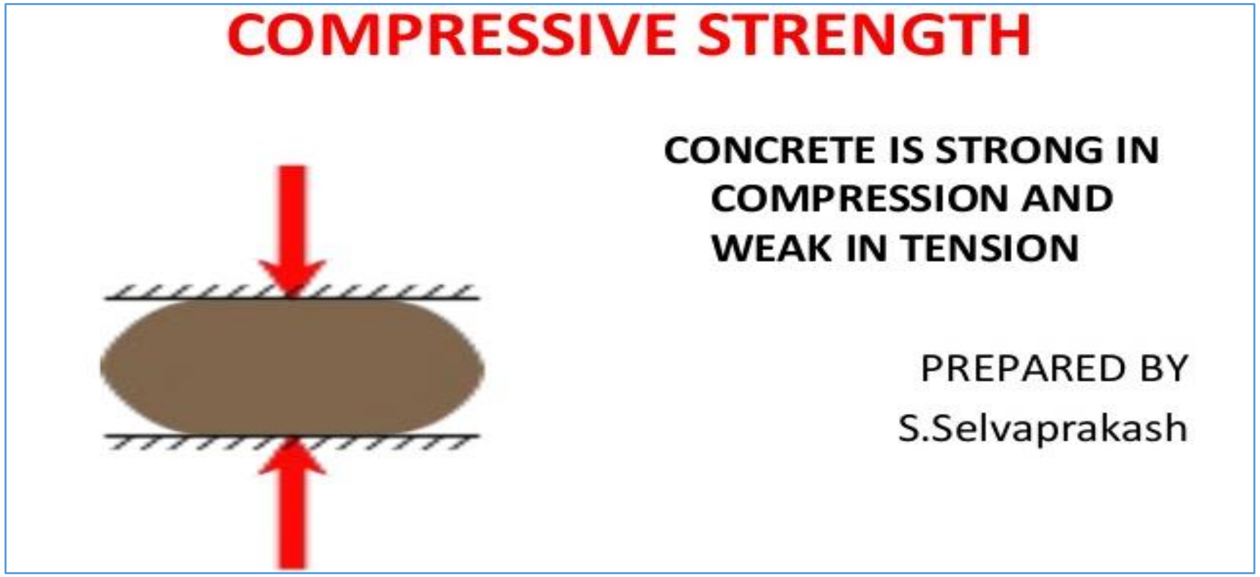


SHEAR STRENGTH
Shear strength is the ability of a metal fractured by opposing forces not acting in to resist being a straight line . Shear strength can be controlled by varying the hardness of the metal.



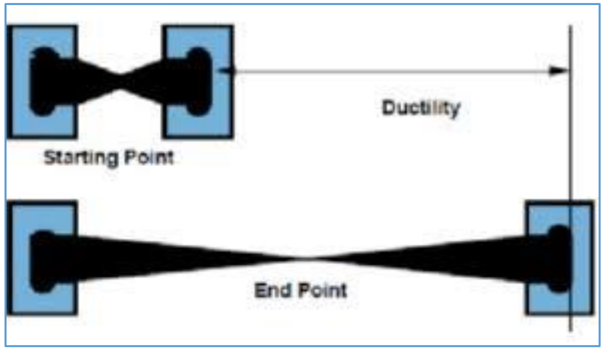
Single Shear Testing　　　Double Shear Testing

COMPRESSIVE STRENGTH
Compressive strength is the ability of a metal to withstand pressures acting on a given plane.

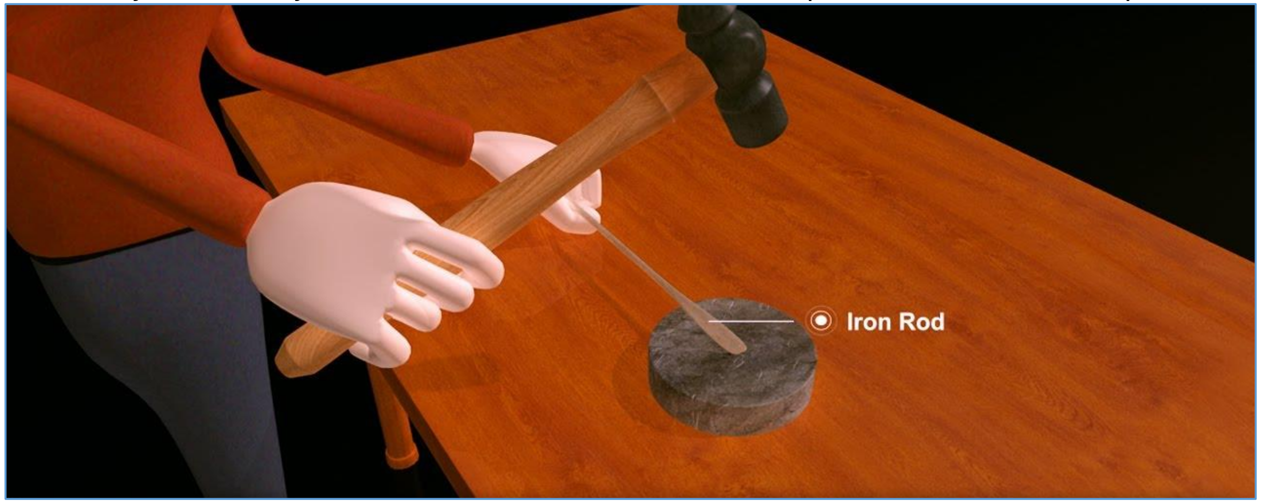


ELASTICITY
Elasticity is the ability of metal to return to its original size and shape after being stretched or pulled out of shape.

DUCTILITY
Ductility is the ability of a metal to be drawn or stretched permanently without rupture or fracture. Metals that lack ductility will crack or break before bending.



MALLEABILITY
Malleability is the ability of a metal to be hammered, rolled, or pressed into various shapes without rupture or fracture.



TOUGHNESS
Toughness is the ability of a metal to resist fracture plus the ability to resist failure after the damage has begun. A tough metal can withstand considerable stress, slowly or suddenly applied, and will deform before failure.

HARDNESS
Hardness is the ability of a metal to resist penetration and wear by another metal or material. It takes a combination of hardness and toughness to withstand heavy pounding. The hardness of a metal limits the ease with which it can be machined, since toughness decreases as hardness increases. The hardness of a metal can usually be controlled by heat treatment.

Knowledge of Stress, strain diagram.

For more details please visit: http://uetmmmksk.weebly.com/uploads/3/6/0/0/3600114/assignment_for_mid_term_exam.pdf

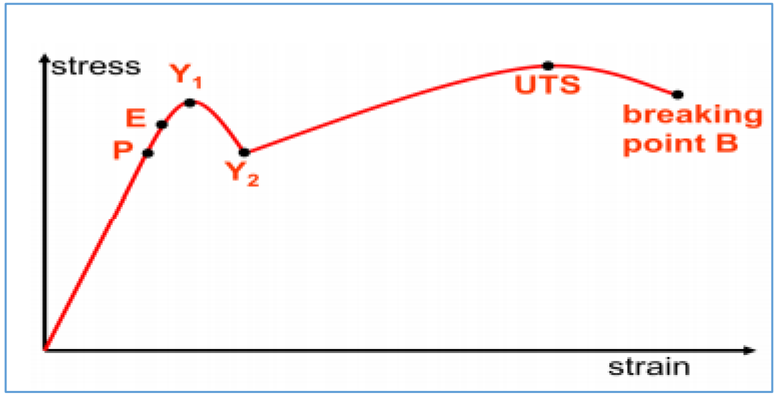
And http://www.uobabylon.edu.iq/eprints/publication_2_20680_1710.pdf

Ductile Materials:

Ductile materials are those which are capable of having large strains before they are fractured. Ductile materials can withstand high stress and are also capable of absorbing large amount of energy before their failure. A ductile material has a large Percentage of elongation before failure. Some examples of ductile materials are aluminum, mild steel and some of its alloys i.e. copper, magnesium, brass, nickel, bronze and many others.

Stress Strain Diagram for Ductile Material:

Proportional Limit (σPL):
Proportional limit is the point on stress strain curve which shows the highest stress at which Stress and Strain are linearly proportional to each other where the proportionality constant is E known as modulus of elasticity. Above this point, stress is no longer linearly proportional to strain. On stress strain curve, proportional limit is shown by P. It is denoted by σPL. For annealed mild steel the limit of proportionality occurs at 230 MPa.



The above graph shows that the length of graph up to proportional limit (P) is a straight line which means that up to proportional limit stress is linearly proportional to strain.

Elastic Limit (σEL):

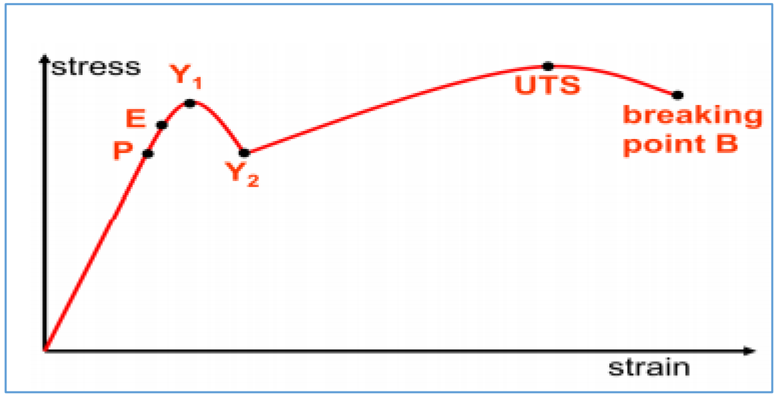
Elastic limit is the point which shows the maximum stress that can be applied to the body without resulting in permanent deformation when stress is removed. At elastic limit when the load is removed from the body, it returns to original size and shape. At elastic limit stress is no longer linearly proportional to strain. It is denoted by σEL. For stress strain graph of mild steel, elastic limit is just close to proportional limit.

Yield point (σY):

Yield point is the point which shows the stress at which a little or no increase in stress results to large increase in strain that is material continues to deform without increase in load. At this point the material will have permanent deformation. It is denoted by σY. For steel, yield point is also just above proportional limit. Yield point is of two types:

- Upper yield point.
- Lower yield point.

Upper yield point is shown by Y1 and lower yield point is shown by Y2 as in diagram given below:



Among the common materials, only steel exhibits yield point. For annealed mild steel, upper yield point occurs at 260 MPa and lower yield point occurs at 230 MPa.

Ultimate Tensile Strength (σU):

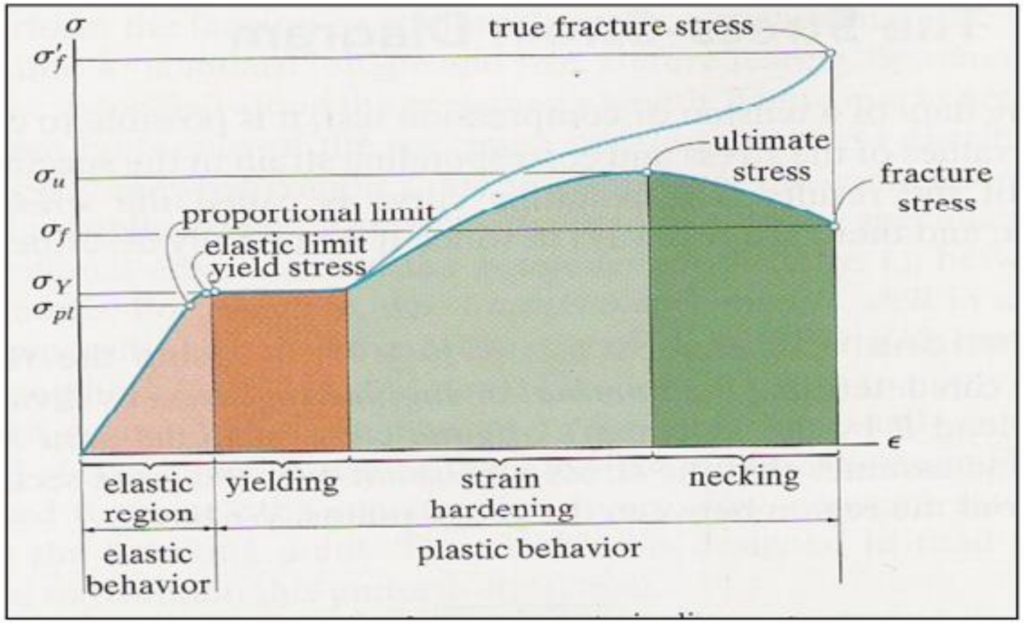
As the stress on material is increased further, the stress and the strain increases from yield point to a point called ultimate tensile strength (UTS) where stress applied is maximum. Thus ultimate tensile strength can be defined as the highest stress on the specimen which it can withstand. For annealed mild steel, ultimate tensile strength occurs at 400 MPa. It is denoted by σU.

Fracture Stress (σF):

After ultimate tensile strength, the applied stress decreases until the stress is obtained where material fractures called fracture stress. Fracture stress is also called breaking strength. It is denoted by σF.

Different Regions under Area of Stress Strain Curve:

This is the general diagram of stress strain curve, which elaborates different regions under stress strain curve.



Elastic region:

Elastic region is the area under the curve from initial point to elastic limit. In this region material will return to its original size and shape when load is removed from the body.

Plastic region:

Plastic region is the area under curve which starts from elastic limit to fracture point. Under the area body shows plastic behavior i.e. when the load is removed from body, it does not come back to its original size and shape.

Yielding region:

This region starts from elastic limit to yield point where the body produces strain with a little or no increase in load.

Strain Hardening:

Area from upper yield point to ultimate tensile stress is called strain hardening. Under this area the body will elongate only with increasing the stress until the stress is at maximum point whereas the cross sectional area will decrease uniformly.

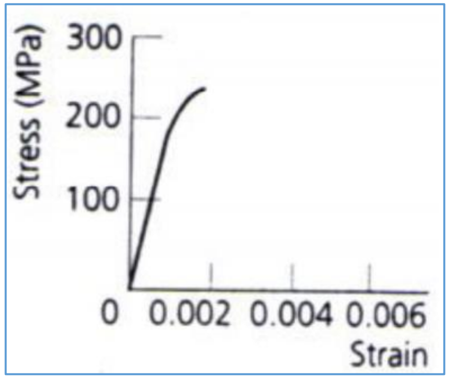
Necking:

Necking covers the area from ultimate tensile stress to fracture point. It is the region where cross sectional area of material will decrease in a localized spot and capacity of material to carry load will decrease. In necking region, stress strain curve has neck like curve.

Brittle Materials:

Brittle materials are those which break suddenly under stress at a point just beyond elastic limit. They have little or no yielding before failure and their percentage of elongation is very low. If percentage elongation is equal to or less than 5%, we consider that material brittle. Brittle materials include glass, concrete, cast iron and plaster.

Stress Strain Diagram for Brittle Materials:



Above graph shows that gray cast iron exhibit less plastic region i.e it fractures just after elastic limit so it is a brittle material.

Young's Modulus:

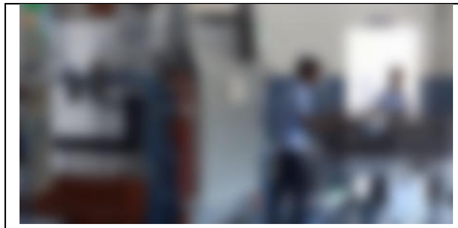
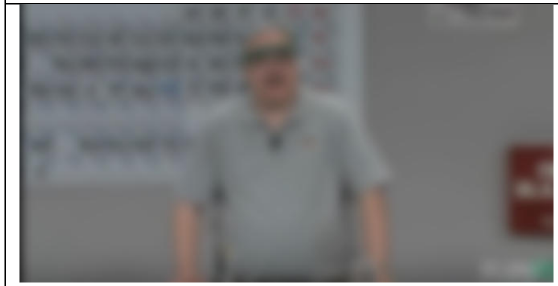
Young's modulus is the ratio of stress applied to the strain under elastic limit. It is given as:

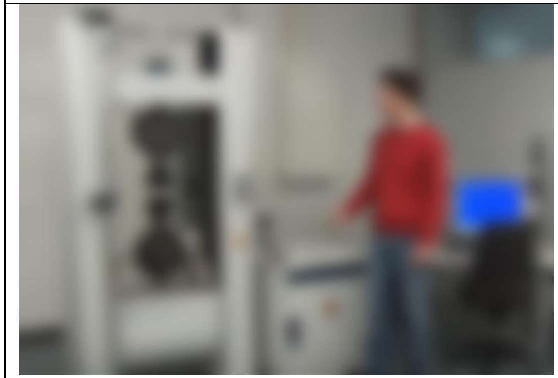
$$\text{Young's Modulus} = \frac{\text{Stress}}{\text{Strain}}$$

$$E = \frac{\sigma}{\varepsilon}$$

It is also known as tensile modulus or modulus of elasticity. By young's modulus, we can measure the stiffness of elastic material.

Video links:

	Heat Treatment Process https://www.youtube.com/watch?v=y6G2eiy6X04
	Heat Treatment of Steel https://www.youtube.com/watch?v=fLvZkZxiXnE

	Super quench + temper https://www.youtube.com/watch?v=4WVWOa_zeQA&list=PLeZsPgc1LNPDJBdgGBB9wBv-Xb_v6UU9T
	Materials Testing - Rockwell Hardness Test https://www.youtube.com/watch?v=NlWVmp_q_XE
	Tensile Test https://www.youtube.com/watch?v=D8U4G5kcpcM

DIES AND MOULDS MAKER

Module-7

LEARNER GUIDE

National Vocational Certificate Level 3

Version 1 - August, 2019

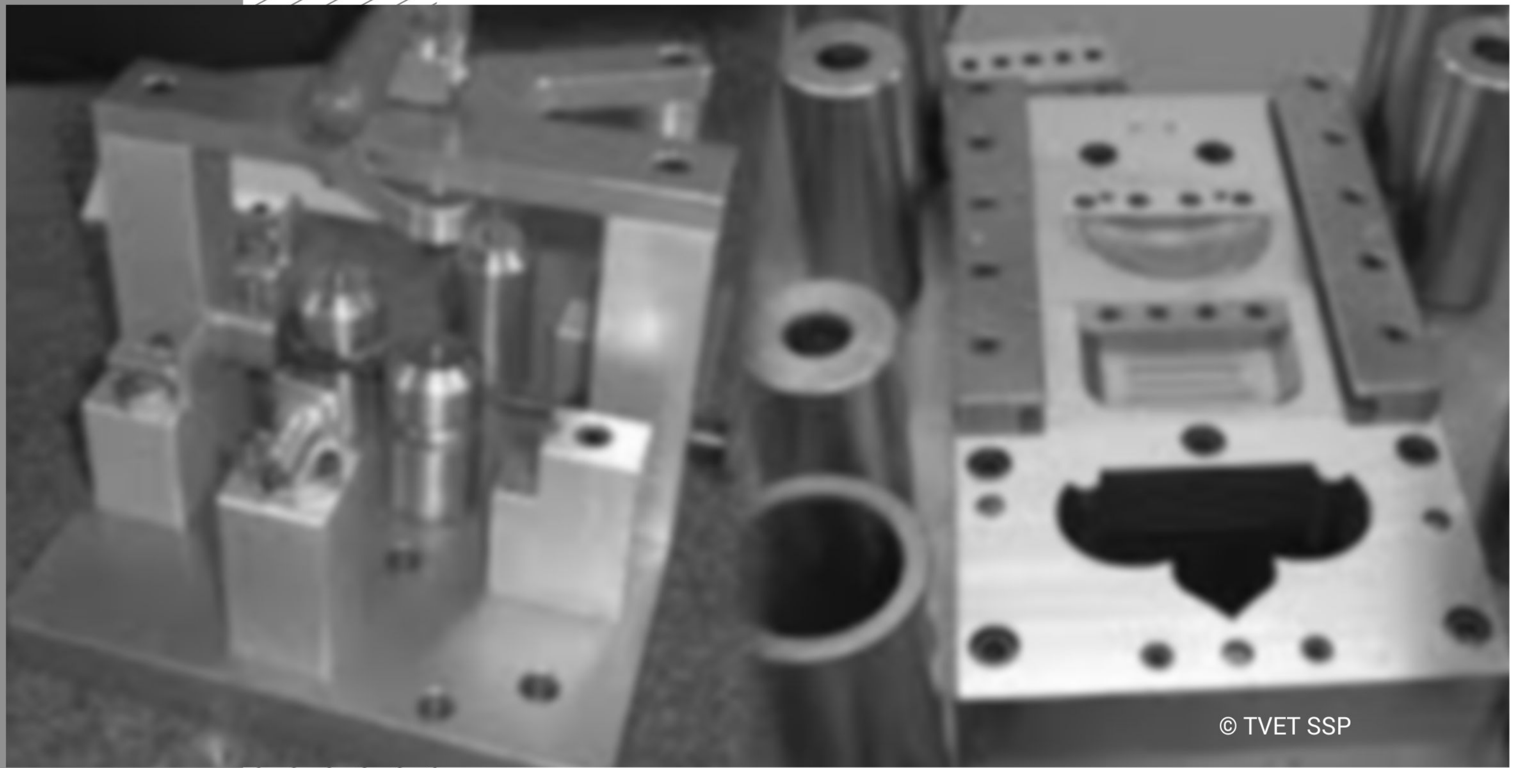
Module 7: Communicate at Work

Objective of the module: This competency standard covers the skills and knowledge required to perform effective communication at work place & outside the organization

Duration:	80 Hrs	**Theory:**	10 Hrs	**Practical:**	70 Hrs

Learning Unit	Learning Outcomes	Learning Elements	Materials Required

DIES AND MOULDS MAKER



Module-8

LEARNER GUIDE

National Vocational Certificate Level 3

Version 1 - August, 2019

Module 8: Take Measures to reduce pollution

Objective of the module: This unit involves the skills and knowledge required for Identifying current workplace resource use to minimize the effects of pollution at workplace and adjoining areas. This involves activities aimed at protecting the ecosystem through pollution prevention and waste minimization, etc. in the areas of air, water and soil.

Duration: Hrs **Theory:** Hrs **Practical:** Hrs

Learning Unit	Learning Outcomes	Learning Elements	Materials Required

Module summary

Module	Learning Unit	Duration
Module 1: Ensure Health and Safety of other individuals at work **Aim:** This unit involves the skills and knowledge required for an individual to not only look after his own but also Health, hygiene and safety of others at work around him.	**LU1:** Identify what can harm people in workplace **LU2:** Identifying who might be harmed **LU3:** Ensure health, hygiene and safety of individuals at work	30 hours

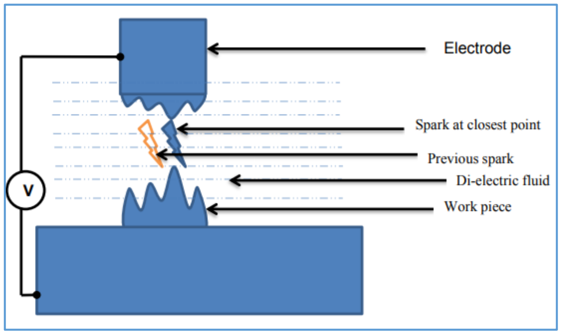
Module	Learning Unit	Duration
Module 2: Perform EDM operations **Aim:** This module describe the performance out comes, skills and knowledge required to perform electric discharge machine .it cover job setting up, running EDM related simulation making and cavities from the machine	**LU1:** Set electrode **LU2:** Set workpiece **LU3:** Set machine parameters **LU4:** Set flushing **LU5:** Carryout machining process **LU6:** Perform final inspection **LU7:** Demonstrate safe working practice and housekeeping	100 hrs

Module	Learning Unit	Duration
Module 3: Perform Wire cut operation **Aim:** This Competency Standard identifies the competencies you need to be competent in CNC wire cut operation in accordance with approval procedure	**LU1:** Set machine programing **LU2:** Set wire **LU3:** Set Di-electric attachment **LU4:** Set machine parameters according to the job **LU5:** Carryout machining process **LU6:** Perform final inspection **LU7:** Demonstrate safe working practice & housekeeping	130 hrs
Module 4: Perform CNC lathe machine **Aim:** This competency standard covers the skills and knowledge required to operate CNC lathe machine safely	**LU1:** Set machine programing **LU2:** Set tool **LU3:** Set workpiece **LU4:** Carryout machining process **LU5:** Perform final inspection **LU6:** Demonstrate safe working practice & housekeeping	200 hrs
Module 5: Perform CNC milling machine operation **Aim:** This competency standard covers the skills and knowledge required to operate CNC Milling machine safely	**LU1:** Set machine programing **LU2:** Set tools **LU3:** Set workpiece **LU4:** Carryout machining process **LU5:** Perform final inspection **LU6:** Demonstrate safe working practice & house keeping	200 hrs

Module	Learning Unit	Duration
Module 6: Perform Heat treatment **Aim:** This standard defines the advanced knowledge, skills and understanding needed to perform heat treatment as per standard procedures	**LU1:** Prepare material for heat treatment **LU2:** Perform stress relieving **LU3:** Perform hardening **LU4:** Perform tempering **LU5:** Perform annealing **LU6:** Perform final inspection **LU7:** Demonstrate safe working practice & housekeeping	80 hrs
Module 7: Communicate at Work **Aim:** This competency standard covers the skills and knowledge required to perform effective communication at work place & outside the organization	**LU1:** Communicate within the organization **LU2:** Communicate outside the organization	

Module	Learning Unit	Duration
Module 8: Take measures to reduce pollution **Aim:** This unit involves the skills and knowledge required for Identifying current workplace resource use to minimize the effects of pollution at workplace and adjoining areas. This involves activities aimed at protecting the ecosystem through pollution prevention and waste minimization, etc. in the areas of air, water and soil.	**LU1:** Ensure efficiency **LU2:** Implement pollution reduction / prevention, abatement & control (PAC) method	

Short Questions/Answers:

What is abbreviation of EDM	The abbreviation of EDM is " Electrical Discharge Machine"
What is working Principle of EDM?	EDM is a thermal process i.e. material is removed by heat. When electrode is brought closer to the work piece, sunk in the dielectric fluid, current is passed to the electrode and the work piece, which generates heat in the form of frequent series of sparks that vaporizes the pieces at the closest point of work piece and electrode. After removing the piece at the closest distance between electrode and work piece, the next spark occurs simultaneously at the next closest point between them and so on. This process results on forming a cavity on the work piece with the shape of the electrode.
Explain EDM working principle with the help of diagram.	
Write applications of EDM machine.	Generally EDM is hugely used for machining burr free intricate shapes as well as narrow slots and blind cavities. Sinking of dies, plastic molding, die casting compacting, cold heading, extrusion, press tools, wire drawings are some of the examples of its application
Write at least three characteristics of electrode material for EDM.	• High electrical conductivity • High thermal conductivity • Higher density • High melting point • Easy manufacturability

	• Cost efficient
Write down major functional parts of an EDM.	An EDM machine has following major aspects. • Controlled axis • Electrical generator • Control panel • Work table • Dielectric fluid container
Write at least three hazard associated with EDM.	• Hazardous smoke, vapors, and aerosols • Decomposition products and heavy metals • Hydrocarbon dielectrics affect the skin. • Sharp-edge metallic particles damages the skin • Possible fire hazard and explosions • Electromagnetic radiation
Describe classes of fire?	• Class A • Class B • Class C • Class D
Write at least three applications of Wire cut.	• Aerospace, Medical, Electronics and Semiconductor applications • Tool & Die making industries. • For cutting the hard Extrusion Dies • In making Fixtures, Gauges & Cams • Cutting of Gears, Strippers, Punches and Dies • Manufacturing hard Electrodes.
How to prepare drawing for a wire	• allocate start / end points, • adding wire offset values,

cut machining process?	• save in machining format, • import export drawing, • loading file on machine
ON what factors the performance of the wire-tool depends?	• Electrical properties of the wire electrode, • Mechanical properties of the wire electrode, • Thermo Physical properties of the wire electrode, • Cross sectional size and shape of the wire electrode.
Define polarity in terms of Wire cut.	Polarity refers to the electrical conditions determining the direction of the current flow relative to the electrode. The polarity of the electrode can be either positive or negative. Depending on the application, some electrode/work metal combination gives better results when the polarity is changed. Generally the graphite, a positive electrode gives better wear condition and negative gives better speed.
Define duty factor in terms of wire cut?	This is an important parameter in the EDM process. This is given by the ratio of the ON time to the total time. If we have a high duty factor then the flushing time is very less and this might lead to the short circuit condition. A small duty factor indicates a high off time and low machining rate. Therefore there has to be a compromise between the two depending on the tool used, the workpiece and the conditions prevailing.
Define CNC machines	Computer Numeric Control (CNC) is the automation of machine tools that are operated by precisely programmed commands encoded on a storage medium (computer command module, usually located on the device) as opposed to controlled manually by hand wheels or levers, or mechanically automated by cams alone. Most NC today is computer (or computerized) numerical control (CNC), in which computers play an integral part of the control.
Describe CNC system Elements?	A typical CNC system consists of the following six elements

	• Part program • Program input device • Machine control unit • Drive system • Machine tool
Define principle views in orthographic projection	There are six principal views in a multi-view orthographic projection. These are the front, back, top, bottom, and left- and right-side views. A drawing can have any combination of views but the three most common views are: • Front view • Side view • Top view.
Define First angle Projection?	First-angle projection places the object on the profile plane with the vertical plane on the left and the horizontal plane on the bottom. This position locates the top view below the front view, the right-side view on the left side of the front view, and the bottom view above the front view. Because the positioning of the views initially seems illogical, first-angle projections is mostly used in asain countries.
Define 3rd angle Projection?	Third-angle projection places the object with the front view projected onto the vertical plane, the top view onto the horizontal plane, and the right-side view onto the profile plane. The arrangement of the three views on paper is logically sequenced. Since the late 1800s, third-angle projection has been the American standard in drafting practice.

Define cutting speed and feed?	**Cutting speed:** The rate of metal removal is from the metal surface, in length, during the machining per unit time. The unit for cutting speed is m/minute. The depth of cut, the feed rate and the cutting speed are dependent of the hardness of the cutting tool material and the hardness of the cutting material: **Feed**: The distance travels by the tool toward the work piece during one rotation of part. Cutting speed and feed determines the surface finish, power requirements, and material removal rate.
Define G code in CNC programing	Codes that begin with 'G' are called preparatory words because they prepare the machine for a certain type of motion.
Define M code in CNC programing	Control machine auxiliary options like coolant and spindle direction. Only one **M-code** can appear in each block of code.
Define F, S and T codes in CNC programing?	• F-code: used to specify the feed rate • S-code: used to specify the spindle speed • T-code: used to specify the tool identification number associated with the tool to be used in subsequent operations.
Describe at least three input devices for CNC milling	• Floppy Drive • USB Flash Drive • Serial Communication • Ethernet Communication • Conversational Programming
Define data processing unit in CNC milling?	On receiving a part program, the DPU firstly interprets and encodes the part program into internal machine codes. The interpolator of the DPU then calculate the intermediate positions of the motion in terms of BLU (basic length unit) which is the smallest unit length that can be handled by the

	controller. The calculated data are passed to CLU for further action.
Define right hand rule for Cartesian coordinate system.	 The Cartesian coordinate system consists of three number lines, labeled X, Y and Z, set at 90 degree angles to each other as shown in Figure below. The origin, or Datum, is where the three axes cross each other. The labels, orientations, and directions of the Cartesian coordinate system in Figure are typical of most Vertical and Horizontal Machining Center (VMC & HMC).
Define CNC machine Jog mode	CNC machine Jog mode is one of the most used CNC mode. Jog mode is mostly used to travel the CNC machine carriage (or CNC machine Slide) such as CNC machine's axis movement e.g. x-axis z-axis. These axis movement can be via axis specific keys or through the CNC machine hand wheel.
Define Program repetition and looping	In actual machining, it is not always possible to machine to the final dimension in one go. This function enables the looping of a portion of the program so that the portion can be executed repeatedly.
Describe stages of a heat treatment process	Stage I — Heat the metal slowly to ensure a uniform temperature. Stage 2 — Soak (hold) the metal at a given temperature for a given time. Stage 3 — Cool the metal to room temperature.
Define Annealing process	Annealing is a process involving heating and cooling, usually applied to produce softening. The term also refers to treatments intended to alter mechanical or physical properties, produce a definite microstructure, or remove gases. The

	temperature of the operation and the rate of cooling depend upon the material being annealed and the purpose of the treatment.
Define Hardening Process	A ferrous metal is normally hardened by heating the metal to the required temperature and then cooling it rapidly by plunging the hot metal into a quenching medium, such as oil, water, or brine. Most steels must be cooled rapidly to harden them. The hardening process increases the hardness and strength of metal, but also increases its brittleness.
Define tempering?	Steel is usually harder than necessary and too brittle for practical use after being hardened. Severe internal stresses are set up during the rapid cooling of the metal. Steel is tempered after being hardened to relieve the internal stresses and reduce its brittleness. Tempering consists of heating the metal to a specified temperature and then permitting the metal to cool. The rate of cooling usually has no effect on the metal structure during tempering. Therefore, the metal is usually permitted to cool in still air. Temperatures used for tempering are normally much lower than the hardening temperatures. The higher the tempering temperature used, the softer the metal becomes. High-speed steel is one of the few metals that becomes harder instead of softer after it is tempered.
Define Quenching Crakes	Quenching cracks occurs when cooling rate is more than critical rate. It is avoided by tempering immediately and avoiding sharp corners.
Describe types of hardness testing methods	Hardness Rockwell C HRC Vickers Brinell

Define tensile strength	Tensile strength is the ability of a metal to resist being pulled apart by opposing forces acting in a straight line. It is expressed as the number of pounds of force required to pull apart a bar of the material 1 inch wide and 1 inch thick.

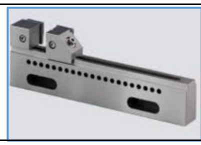
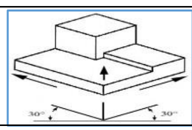
Test Yourself (Multiple Choice Questions)

MODULE	2			
Question	**1**	In an EDM the material removal is done though?	A	Fluid
			B	Pressure
			C	Heat
			D	Gas
Question	**2**	**What material cannot be machined on an EDM machine?**	A	Mild Steel
			B	Carbon Steel
			C	Copper

			D	Glass
Question	**3**	**To machine a material on EDM it must be ……?**	A	An Insulator
			B	A Conductor
			C	A Semi-Conductor
			D	Transparent

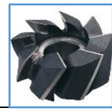
Question	**4**	What characteristics should an electrode material have?	A	High electrical conductivity
			B	High thermal conductivity
			C	Higher density
			D	All of above
Question	**5**	Accurate use of a dial indicator requires?	A	Oiling
			B	Rigid mounting
			C	Rough surface
			D	All of above
MODULE	**3**			
Question	**6**	The produces for each electric spark in wire cut is?	A	400 to 600 Degree Fahrenheit
			B	8000 to 16000 Degree Fahrenheit
			C	15000 to 21000 Degree Fahrenheit

			D	40000 to 60000 Degree Fahrenheit
Question	**7**	Higher the pulse ON time results increased_____________	A	Material removal
			B	finishing
			C	Machining time
			D	Cleaning time

Question	**8**	Gap Voltage is also called?	A	Off time
			B	Pulse time
			C	Finish time
			D	Open circuit voltage
Question	**9**	The Part shown in the figure is a ?	A	Wire gauge
			B	Wire cutter
			C	EDM fixture
			D	Wire Cut vise
MODULE	**4**			
Question	**10**	The view shown in the figure is an example of:	A	Orthographic Projection
			B	Isometric Projection
			C	Side view
			D	Plan view
Question	**11**	In CNC programing “G00” is used for?	A	Rapid movement

			B	Slow movement
			C	Feed rate
			D	Spindle speed
Question	**12**	For CNC programing what G code is used for tool length Compensation plus?	A	G02
			B	G03
			C	G43
			D	G17
Question	**13**	For CNC programing what G code is used for tapping mode?	A	G63
			B	G70
			C	G72
			D	G75
Question	**14**	What code gives an identifying number for each block of information	A	X

			B	Y
			C	Z
			D	N
MODULE	**5**			
Question	**15**	CNC machines are widely used in?	A	Garment industry
			B	Metal cutting industry
			C	Pipe producing industry
			D	Bottle filling industry

Question	**16**	The tool shown in the figure is a?	A	End mill cutter
			B	Shell end mill cutter
			C	Face mill cutter
			D	Dovetail cutter
Question	**17**	The tool shown in the figure is a?	A	End mill cutter
			B	Shell end mill cutter
			C	Face mill cutter
			D	Dovetail cutter
Question	**18**	The tool shown in the figure is a?	A	End mill cutter
			B	Shell end mill cutter
			C	Face mill cutter
			D	Dovetail cutter

Question	**19**	The tool shown in the figure is a?	A	End mill cutter
			B	Shell end mill cutter
			C	Face mill cutter
			D	Dovetail cutter
Module	**6**			
Question	**20**	A material property of resistance to indent or scratch is known as?	A	Toughness
			B	Hardness
			C	Ductility
			D	Malleability
Question	**21**	A material property of resistance to impact forces is known as?	A	Toughness
			B	Hardness
			C	Ductility
			D	Malleability

Question	**22**	The ability of material to deform under compression is known as?	A	Toughness
			B	Hardness
			C	Ductility
			D	Malleability
Question	**23**	The ability of material which doesn't allow material to with stand impact forces is known as?	A	Toughness
			B	Hardness
			C	Brittleness
			D	Malleability

Test Yourself (Multiple Choice Questions)

MODULE	**2**			
Question	**1**	In an EDM the material removal is done though?	A	Fluid
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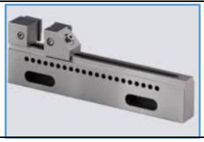
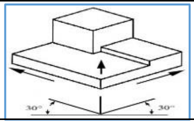
			C	Copper

			D	Glass
Question	**3**	To machine a material on EDM it must be ……?	A	An Insulator
			B	A Conductor
			C	A Semi-Conductor
			D	Transparent

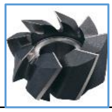
Question	**4**	What characteristics should an electrode material have?	A	High electrical conductivity
			B	High thermal conductivity
			C	Higher density
			D	All of above
Question	**5**	Accurate use of a dial indicator requires?	A	Oiling
			B	Rigid mounting
			C	Rough surface
			D	All of above
MODULE	**3**			
Question	**6**	The produces for each electric spark in wire cut is?	A	400 to 600 Degree Fahrenheit
			B	8000 to 16000 Degree Fahrenheit
			C	15000 to 21000 Degree Fahrenheit

			D	40000 to 60000 Degree Fahrenheit
Question	**7**	Higher the pulse ON time results increased_____________	A	Material removal
			B	finishing
			C	Machining time
			D	Cleaning time

Question	**8**	Gap Voltage is also called?	A	Off time
			B	Pulse time
			C	Finish time
			D	Open circuit voltage
Question	**9**	The Part shown in the figure is a ?	A	Wire gauge
			B	Wire cutter
			C	EDM fixture
			D	Wire Cut vise
MODULE	**4**			
Question	**10**	The view shown in the figure is an example of:	A	Orthographic Projection
			B	Isometric Projection
			C	Side view
			D	Plan view
Question	**11**	In CNC programing "G00" is used for?	A	Rapid movement

			B	Slow movement
			C	Feed rate
			D	Spindle speed
Question	**12**	For CNC programing what G code is used for tool length Compensation plus?	A	G02
			B	G03
			C	G43
			D	G17
Question	**13**	For CNC programing what G code is used for tapping mode?	A	G63
			B	G70
			C	G72
			D	G75
Question	**14**	What code gives an identifying number for each block of information	A	X

			B	Y
			C	Z
			D	N
MODULE	**5**			
Question	**15**	CNC machines are widely used in?	A	Garment industry
			B	Metal cutting industry
			C	Pipe producing industry
			D	Bottle filling industry

Question	**16**	The tool shown in the figure is a?	A	End mill cutter
			B	Shell end mill cutter
			C	Face mill cutter
			D	Dovetail cutter
Question	**17**	The tool shown in the figure is a?	A	End mill cutter
			B	Shell end mill cutter
			C	Face mill cutter
			D	Dovetail cutter
Question	**18**	The tool shown in the figure is a?	A	End mill cutter
			B	Shell end mill cutter
			C	Face mill cutter
			D	Dovetail cutter

Question	**19**	The tool shown in the figure is a?	A	End mill cutter
			B	Shell end mill cutter
			C	Face mill cutter
			D	Dovetail cutter
Module	**6**			
Question	**20**	A material property of resistance to indent or scratch is known as?	A	Toughness
			B	Hardness
			C	Ductility
			D	Malleability
Question	**21**	A material property of resistance to impact forces is known as?	A	Toughness
			B	Hardness
			C	Ductility
			D	Malleability

Question	**22**	The ability of material to deform under compression is known as?	A	Toughness
			B	Hardness
			C	Ductility
			D	Malleability
Question	**23**	The ability of material which doesn’t allow material to with stand impact forces is known as?	A	Toughness
			B	Hardness
			C	Brittleness
			D	Malleability

Multiple Choice Questions Answers Scheme

MODULE	**2**			
Question	**1**	In an EDM the material removal is done though?	C	Heat
Question	**2**	What material cannot be machined on an EDM machine?	D	Glass
Question	**3**	To machine a material on EDM it must be ……?	B	A Conductor
Question	**4**	What characteristics should an electrode material have?	D	All of above
Question	**5**	Accurate use of a dial indicator requires?	B	Rigid mounting
MODULE	**3**			
Question	**6**	The produces for each electric spark in wire cut is?	C	15000 to 21000 Degree Fahrenheit
Question	**7**	Higher the pulse ON time results increased_____________	A	Material removal
Question	**8**	Gap Voltage is also called?	D	Open circuit voltage
Question	**9**	The Part shown in the figure is a ?	D	Wire Cut vise

MODULE	4			
Question	**10**	The view shown in the figure is an example of:	B	Isometric Projection
Question	**11**	In CNC programing “G00” is used for?	A	Rapid movement
Question	**12**	For CNC programing what G code is used for tool length Compensation plus?	C	G43
Question	**13**	For CNC programing what G code is used for tapping mode?	A	G63
Question	**14**	What code gives an identifying number for each block of information	D	N

MODULE	**5**			
Question	**15**	CNC machines are widely used in?	B	Metal cutting industry
Question	**16**	The tool shown in the figure is a?	B	Shell end mill cutter
Question	**17**	The tool shown in the figure is a?	A	End mill cutter
Question	**18**	The tool shown in the figure is a?	C	Face mill cutter
Question	**19**	The tool shown in the figure is a?	D	Dovetail cutter
Module	**6**			
Question	**20**	A material property of resistance to indent or scratch is known as?	B	Hardness
Question	**21**	A material property of resistance to impact forces is known as?	A	Toughness
Question	**22**	The ability of material to deform under compression is known as?	D	Malleability
Question	**23**	The ability of material which doesn’t allow material to with stand impact forces is known as?	C	Brittleness

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