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Traditional Craft Heritage Training , Design & Marketing in Jordan and Syria
(HANDS)

Project Number: 610238-EPP-1-2019-1-JO-EPPKA2-CBHE-JP

Materials and Manufacturing process

Course Offered By : ZUJ,ABU,TU

Module 5

Responsible partner(s):

Training and Technical Group (TTG)

Scientific and Supervising Committee (SC)

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SPECIFIC COURSE INFORMATION

CATALOG DESCRIPTION: INTRODUCTION TO MANUFACTURING;

FUNDAMENTAL PROPERTIES OF ENGINEERING MATERIALS, FORMING AND SHAPING PROCESSES, SUCH AS ROLLING, FORGING, EXTRUSION, DRAWING, SHEET METAL FORMING, POWDER METALLURGY; FUNDAMENTALS OF MACHINING, MACHINING PROCESSES, MACHINE TOOL MATERIALS AND ADVANCED MACHINING PROCESSES METAL CASTING FUNDAMENTALS AND METAL CASTING PROCESSES; JOINING PROCESSES; SURFACE TECHNOLOGY.

COURSE HANDS LEARNING OUTCOMES

LO12: Explore creative expression and innovation within traditional craft design. This involve experimentation with materials, techniques, and forms to create contemporary interpretations of traditional crafts.

LO13: Consider the environmental impact of traditional craft practices and explore sustainable approaches to materials sourcing, production processes, and waste management within the context of traditional craft design.

LO18: Knowledge of the materials traditionally used in crafts, including their properties, sourcing, preparation, and appropriate usage. This involve understanding natural materials like clay, wood, fibers, or metals, as well as any modern substitutes or adaptations.

LO19: Apply traditional design principles to the manufacturing processes, ensuring that design work reflects the aesthetic and functional qualities inherent in traditional craft objects. This includes considerations of form, function, ornamentation, and cultural symbolism.

LO21: Optimizing manufacturing processes for efficiency and productivity. This includes streamlining workflows, minimizing waste, and maximizing output without compromising quality

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TOPICS COVERED:

- APPLICATION OF ANY EXISTING MANUFACTURING PROCESS AND SYSTEM
- FUNDAMENTALS OF METAL FORMING
- MACHINING
- METAL CASTING
- POWDER METALLURGY
- WELDING
- SURFACE TECHNOLOGY

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Introduction to Craft Manufacturing

The process of crafting products using hands, tools, and machines involves creativity and skill.

1 **Origins**

Craft manufacturing dates back to ancient civilizations, where artisans handcrafted items for daily use.

2 **Medieval Guilds**

The medieval era saw the formation of craft guilds, preserving traditional techniques and knowledge.

3 **Industrial Revolution**

The advent of machinery reshaped craft manufacturing, leading to mass production and standardization.

4 **Artisan Revival**

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Modern Craft Manufacturing

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3D Printing

Innovative technology revolutionizing the creation of intricate craft designs.

Robotics

Automation enhancing precision and efficiency in crafting processes.

Computer-Aided Design

Software enabling digital prototyping and visualization of crafts.

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Challenges in the Craft Manufacturing Industry

Economic Pressures

Competing with mass-produced, cheaper alternatives is a considerable challenge.

Skill Preservation

The risk of traditional craft skills being lost in the face of modernization.

Market Access

Accessing global markets and competing with larger, commercial manufacturers.

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Future Trends in Craft Manufacturing

1

Customization

Rising demand for unique, personalized craft products tailored to individual preferences.

2

Digital Integration

The integration of digital platforms for marketing, sales, and distribution.

3

Sustainable Practices

An increased emphasis on environmentally conscious and ethical production methods.

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ENGINEERING MATERIALS

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ENGINEERING MATERIALS

The substances which are useful in the field of engineering are called Engineering materials. A particular material is selected is on the basis of following considerations

1. Properties of material

Mechanical properties – strength, ductility, toughness, hardness,strength to weight ratio etc.

Physical properties – density, specific heat, thermal expansion,conductivity , melting point. Chemical properties – oxidation , corrosion, flammability, toxicity etc.

Manufacturing properties – formed, casting, machined, welding

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ENGINEERING MATERIALS

The substances which are useful in the field of engineering are called Engineering materials. A particular material is selected is on the basis of following considerations

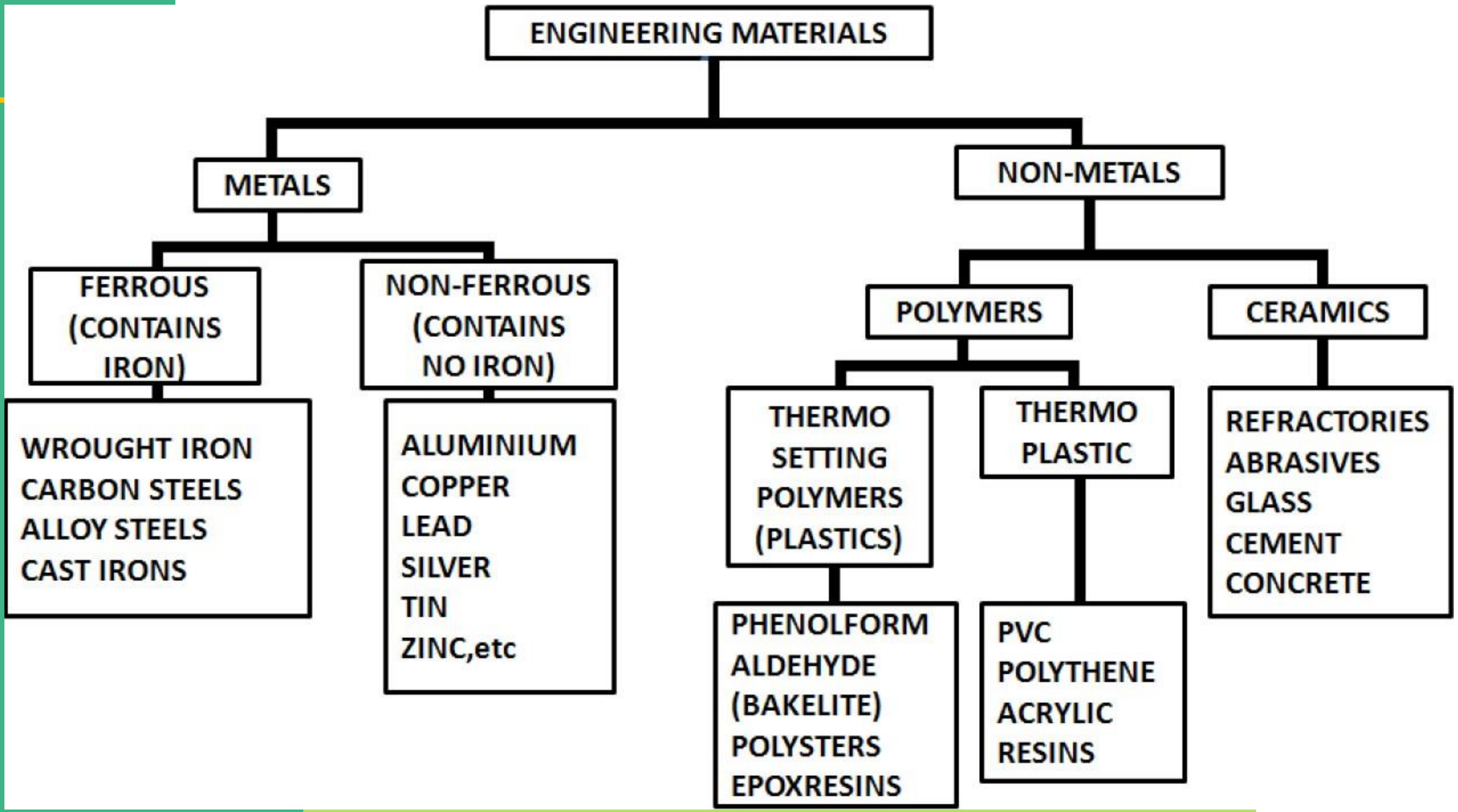
2. **Cost of material**
3. **Availability of material (desired shape and size and quantity) reliability of supply.**
4. **Service in life of material**

Dimensional stability of material wear, corrosion etc., shorten life

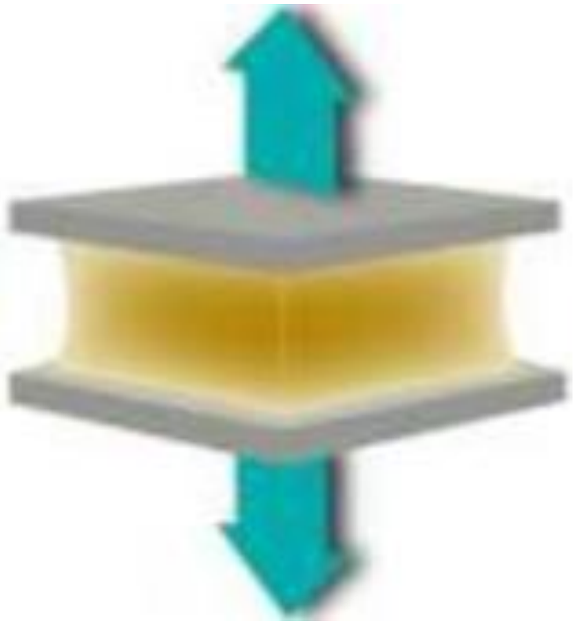
5. **Appearance of material**

Color
Surface texture etc.

CLASSIFICATION OF ENGINEERING MATERIALS



MECHANICAL PROPERTIES



STRENGTH :

It is defined as the ability of a material to resist loads without failure.
It is usually expressed or measured in terms of maximum load per unitarea(i.e maximum stress or ultimate strength) that a material can withstand failure and it varies according to the type of loading .
Further the strength is divided into three types they are

Tensile Strength:

The tensile strength or tenacity is defined as the ability of material to resist a stretching (tensile) load without fracture.

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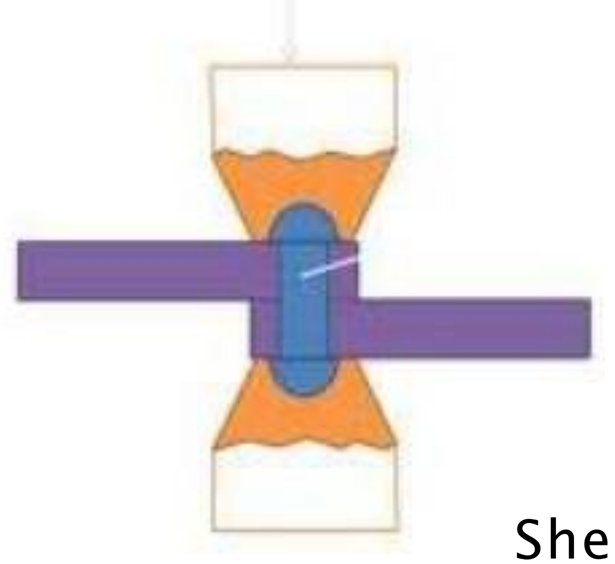
MECHANICAL PROPERTIES

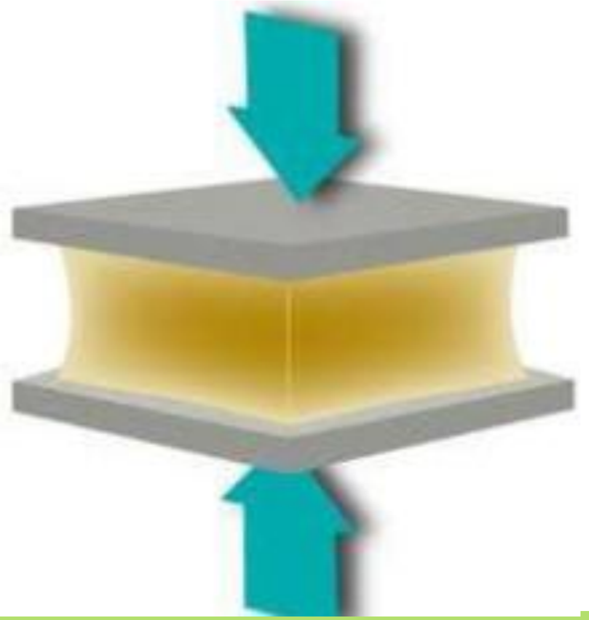
Compressive strength :
The ability of a material to resist squeezing (compressive) load without fracture is called compressive strength.

Shear strength :
The ability of a material to resist transverse loads i.e. loads tending to separate (or cut) the material is called shear strength.

STIFFNESS :
It is the ability of material to resist deformation or deflection under load. Within the elastic limit, stiffness is measured by the modulus of elasticity.



Shear strength



Compressive strength

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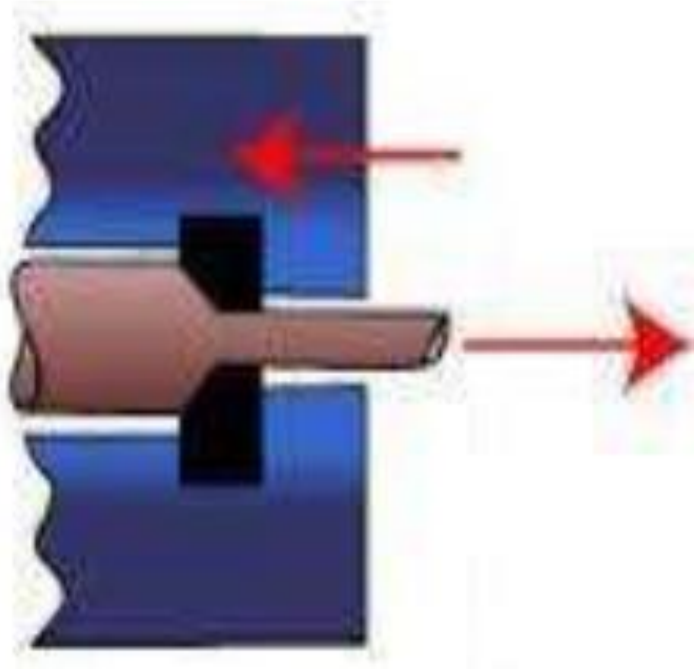
MECHANICAL PROPERTIES

ELASTICITY :
The ability of a material to deform under load and return to its original shape when the load is removed is called elasticity.

PLASTICTY :
The ability of a material to deform under load and retain its new shape when the load is removed is called plasticity.



Ductility

It is the ability of a material to be deformed plastically without rupture under tensile load. Due to this property material can drawn out into fine wire without fracture.

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MECHANICAL PROPERTIES

MALLEABILTY :
It is the ability of a material to be deformed plastically without rupture under compressive load. Due to this property metals are hammered and rolled into thin sheets.

TOUGHNESS :
It is defined as the ability of the material to absorb energy up to fracture during the plastic deformation. Toughness of a metal offers the resistance to breaking when force is applied.

It is the property of sudden fracture without any visible permanent deformation.

Malleability

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MECHANICAL PROPERTIES

HARDNESS :

It is defined as the ability of a material to resist scratching or indentation by another hard body. Hardness is directly related to strength.

CREEP :

The slow and progressive deformation of a material with time at constant stress is called creep.

FATIGUE :

Failure of material under repeated or reversal stresses is called fatigue. Machine parts are frequently subjected to varying stresses and it is important to know the strength of materials in such conditions. The maximum stress at which the material will operate indefinitely without failure is known as the endurance limit or fatigue limit.

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MECHANICAL PROPERTIES

RESILIENCE :
It is a property of material to absorb energy and to resist shock and impact loads. It is measured by the amount of energy absorbed per unit volume within the elastic limit.

MACHINABILITY:
The ease with which a given material may be worked or shaped with a cutting tool is called machinability. Machinability depends on chemical composition, structure and mechanical properties

WELDABILITY:
It is the ability of material to be joined by welding. Weldability depends on chemical composition, physical properties and heat treatment to which they are subjected.

MECHANICAL PROPERTIES

CASTABILITY :
Castability of metal refer to the ease with which it can be cast into different shapes and is concerned with the behavior of metal in its molten state.

STRAIN HARDENING :
The strengthening effect produced in metals by plastic deformation (cold working) is called strain hardening or work hardening. Strain hardening reduces ductility and corrosion resistance but, raises the hardness and electrical resistance.

FORGING

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SUBJECTS OF INTEREST

- Introduction/objectives
- Classification of forging processes
  - Hammer or drop forging
  - Press forging
  - Open-die forging
  - Closed-die forging
- Calculation of forging loads
- Effect of forging on microstructure
- Residual stresses in forgings
- Typical forging defects

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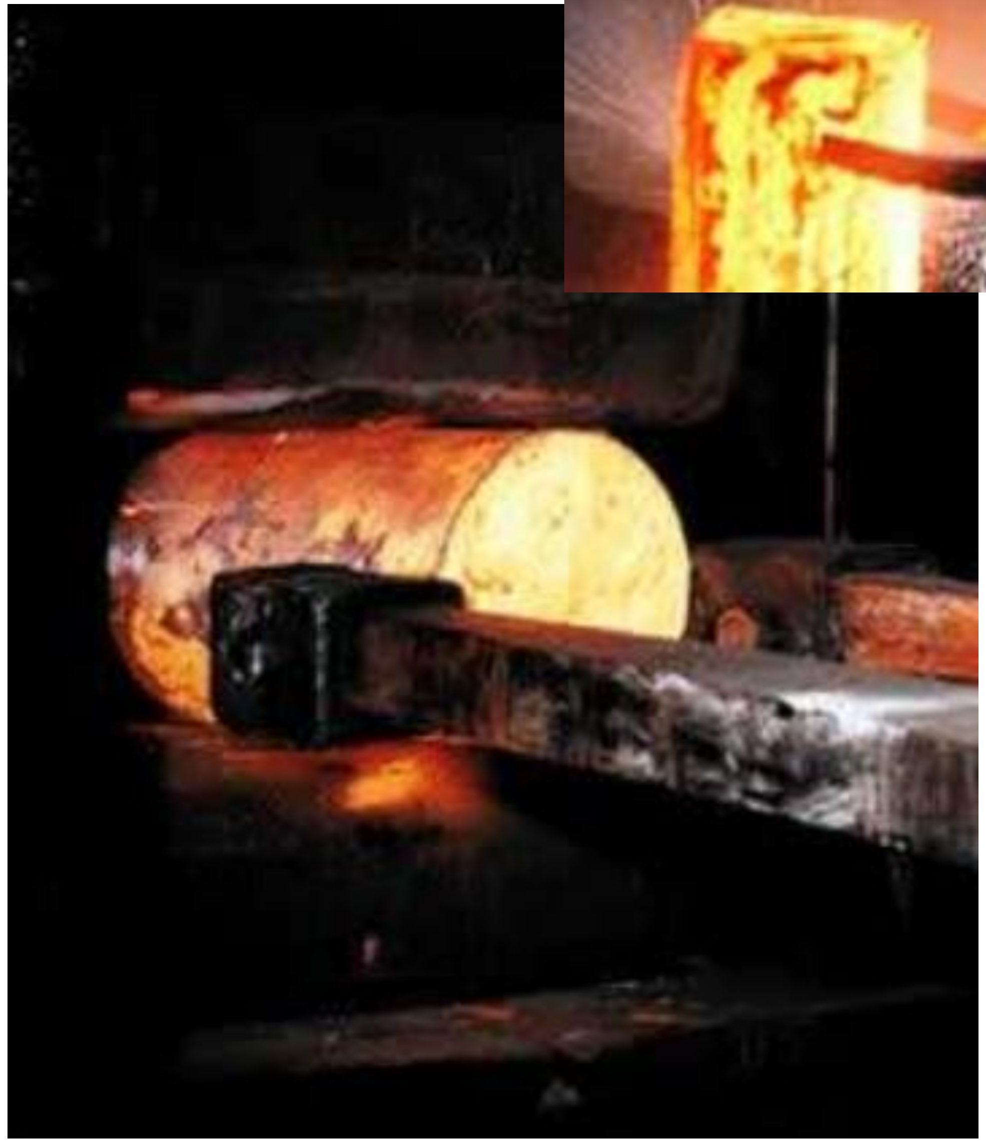
OBJECTIVES

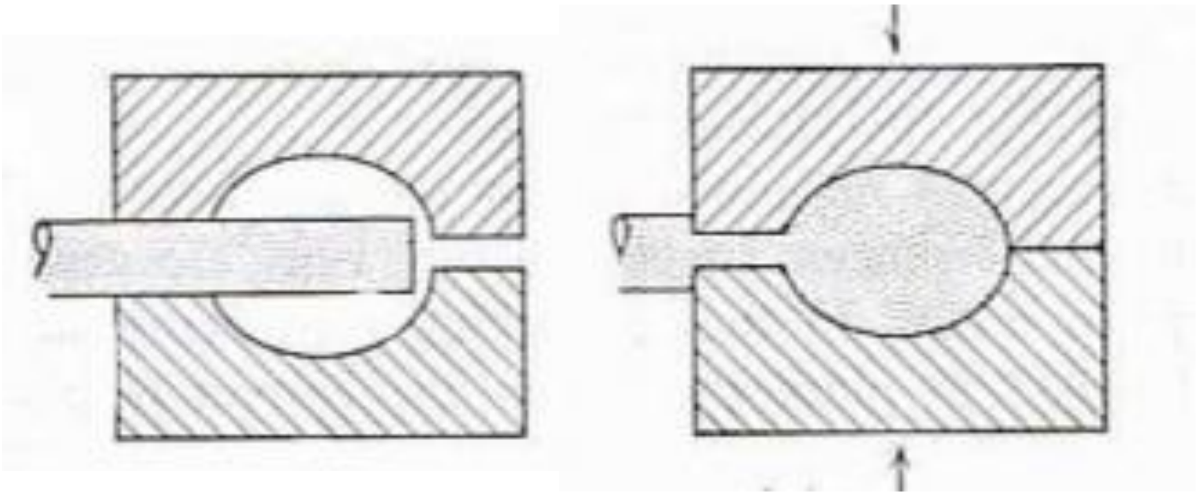
- This chapter provides fundamental of metal working process for forging in order to understand mathematical approaches used in the calculation of applied forging loads required to cause plastic deformation to give the final product.
- Classification of metal forging methods is also provided with descriptions of defects observed from the forging processes.
- The solutions to tackle such defects will also be addressed.

INTRODUCTION

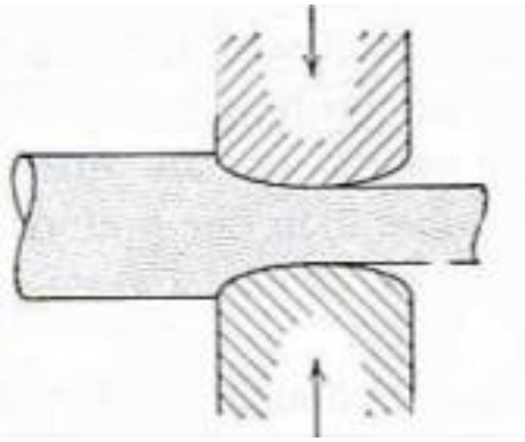
- **Forging** is the working of metal into a useful shape by hammering or pressing.
- The oldest of the metalworking arts (primitive blacksmith).
- Replacement of machinery occurred during early the **Industrial revolution.**
- Forging machines are now capable of making parts ranging in size of **a bolt to a turbine rotor**.
- Most forging operations are carried out **hot**, although certain metals may be **cold-forged**.



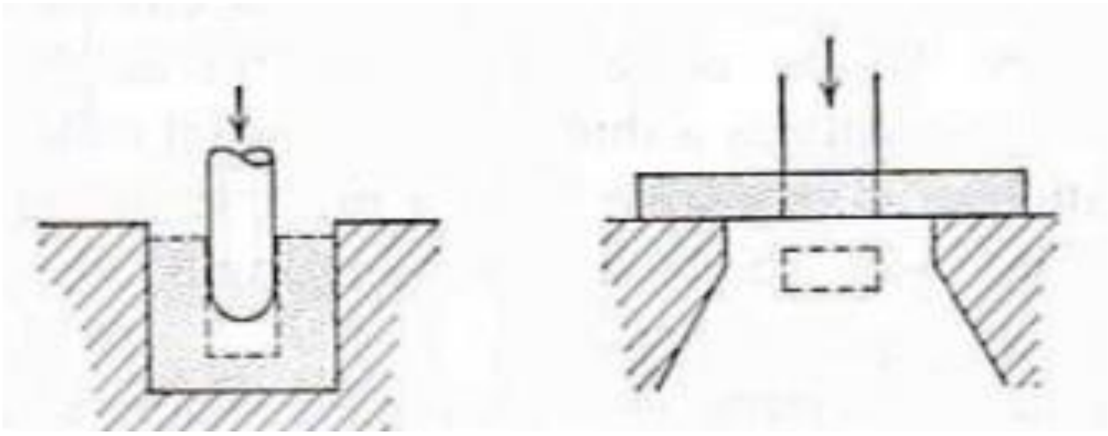
FORGING OPERATIONS



Edging is used to shape the ends of the bars and to gather metal. The metal flow is confined in the horizontal direction but it is free to flow laterally to fill the die.



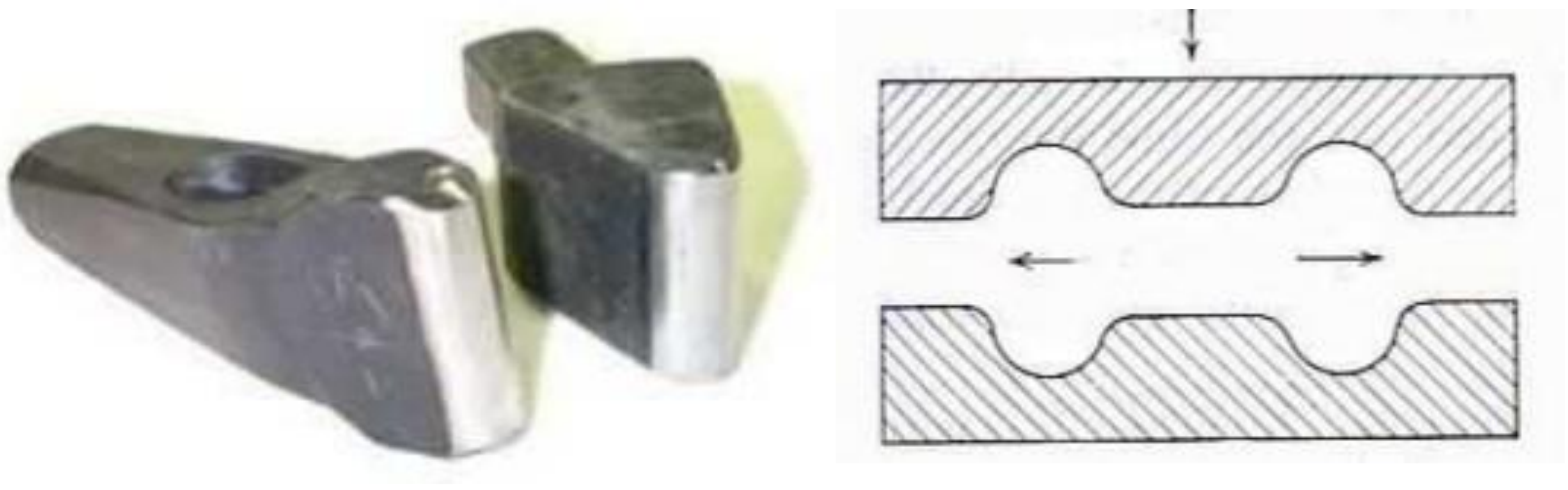
Drawing is used to reduce the cross-sectional area of the workpiece with concurrent increase in length.



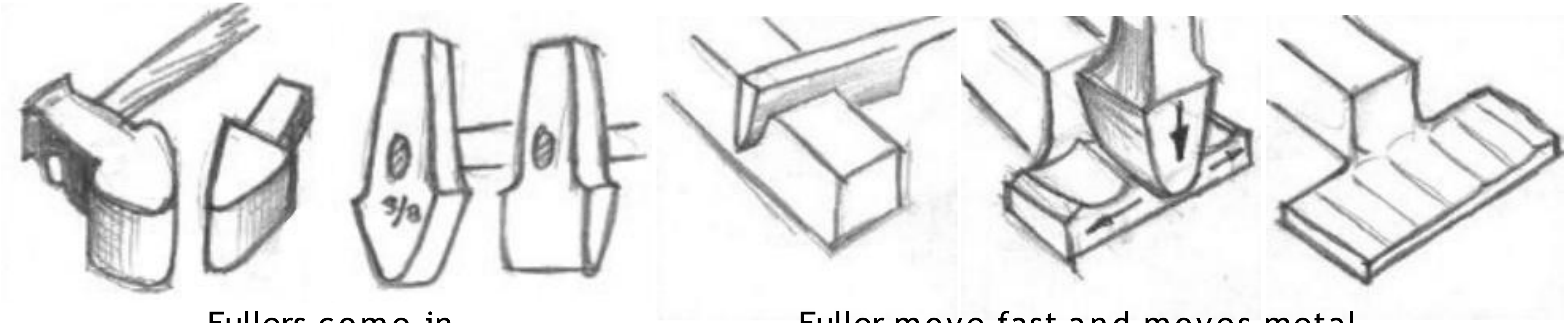
Piercing and punching are used to produce holes in metals.

FORGING OPERATIONS

Fullering is used to reduce the cross-sectional area of a portion of the stock. The metal flow is outward and away from the centre of the fuller. i.e., forging of connecting rod for an internal combustion engine.



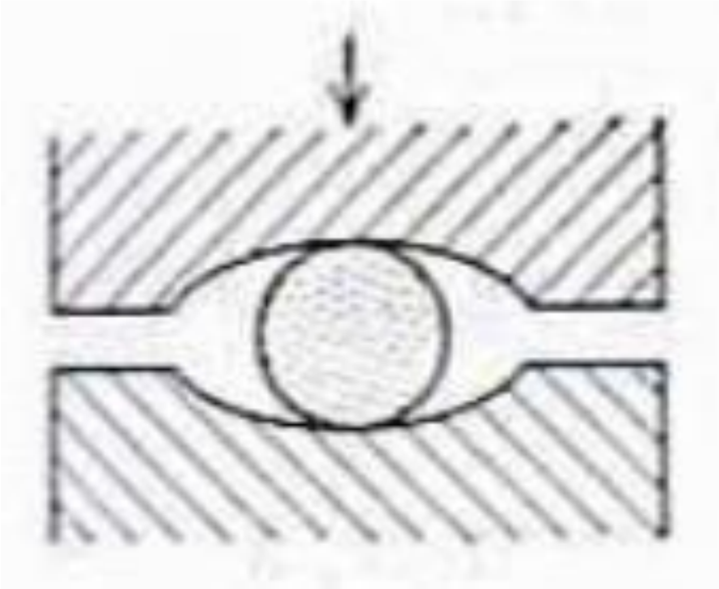
Fullers



Fullers come in different shapes

Fuller move fast and moves metal perpendicular to the face

FORGING OPERATIONS



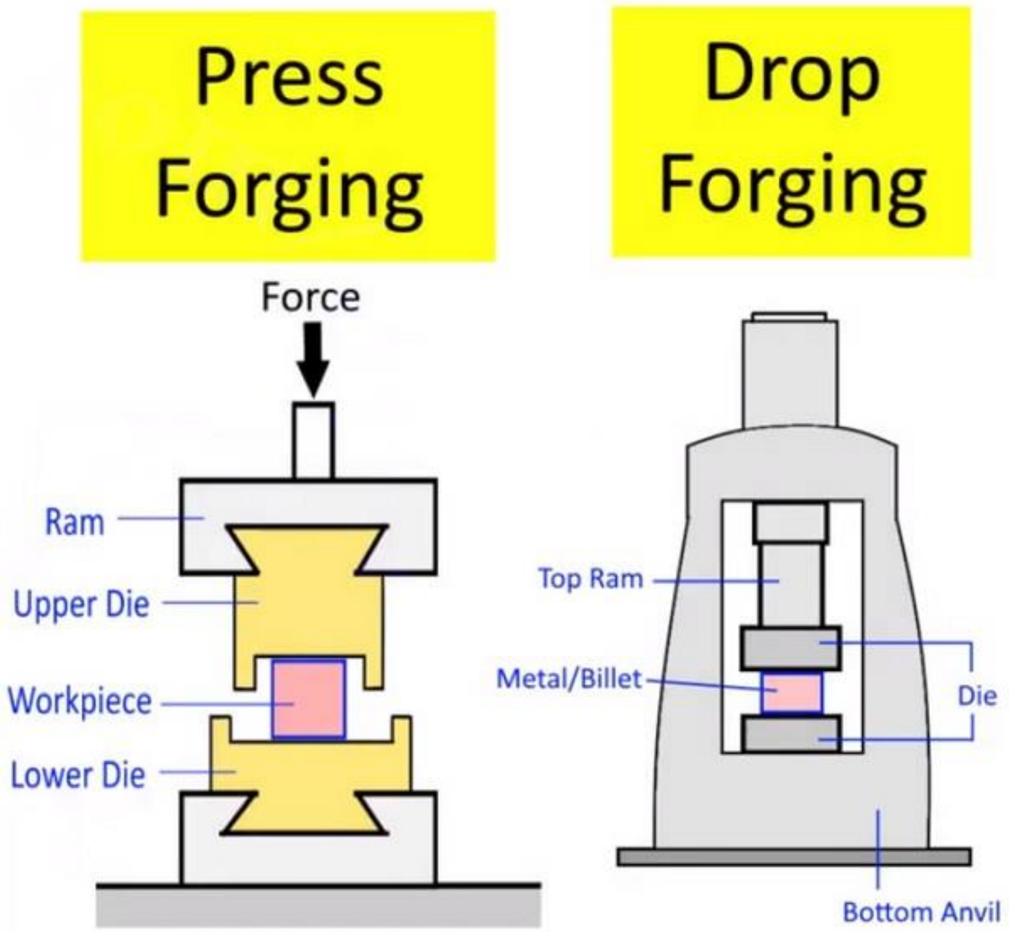
- **Swaging** is used to produce a bar with a smaller diameter (using concave dies).

Swaging at the ends, ready for next forming process.

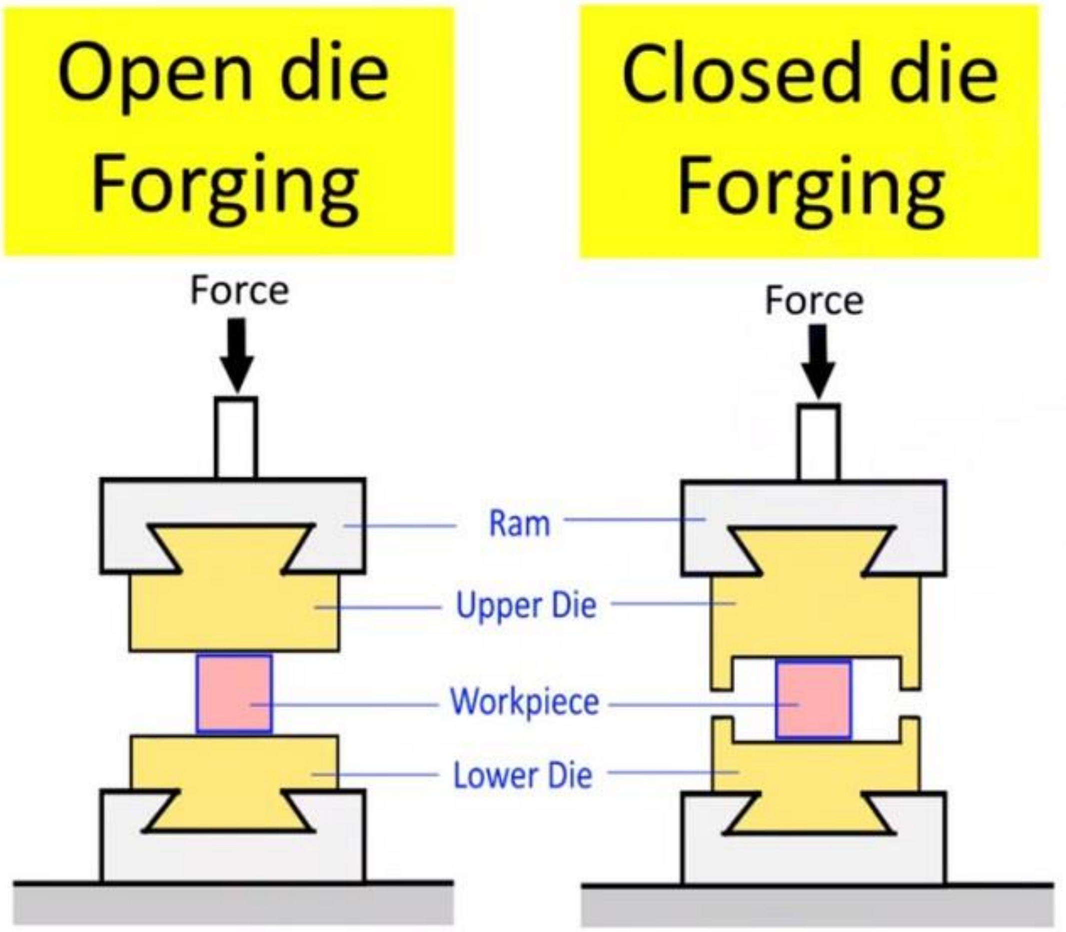
- Swaging is a special type of forging in which metal is formed by a succession of rapid hammer blows.
- Swaging provides a reduced round cross section suitable for tapping, threading, upsetting or other subsequent forming and machining operations.

CLASSIFICATION OF FORGING PROCESSES

- **By equipment**
  - Forging hammer or drop hammer
  - Press forging



- **By process**
  - Open - die forging
  - Closed - die forging



FORMING MACHINES

There are four basic types of forging machines

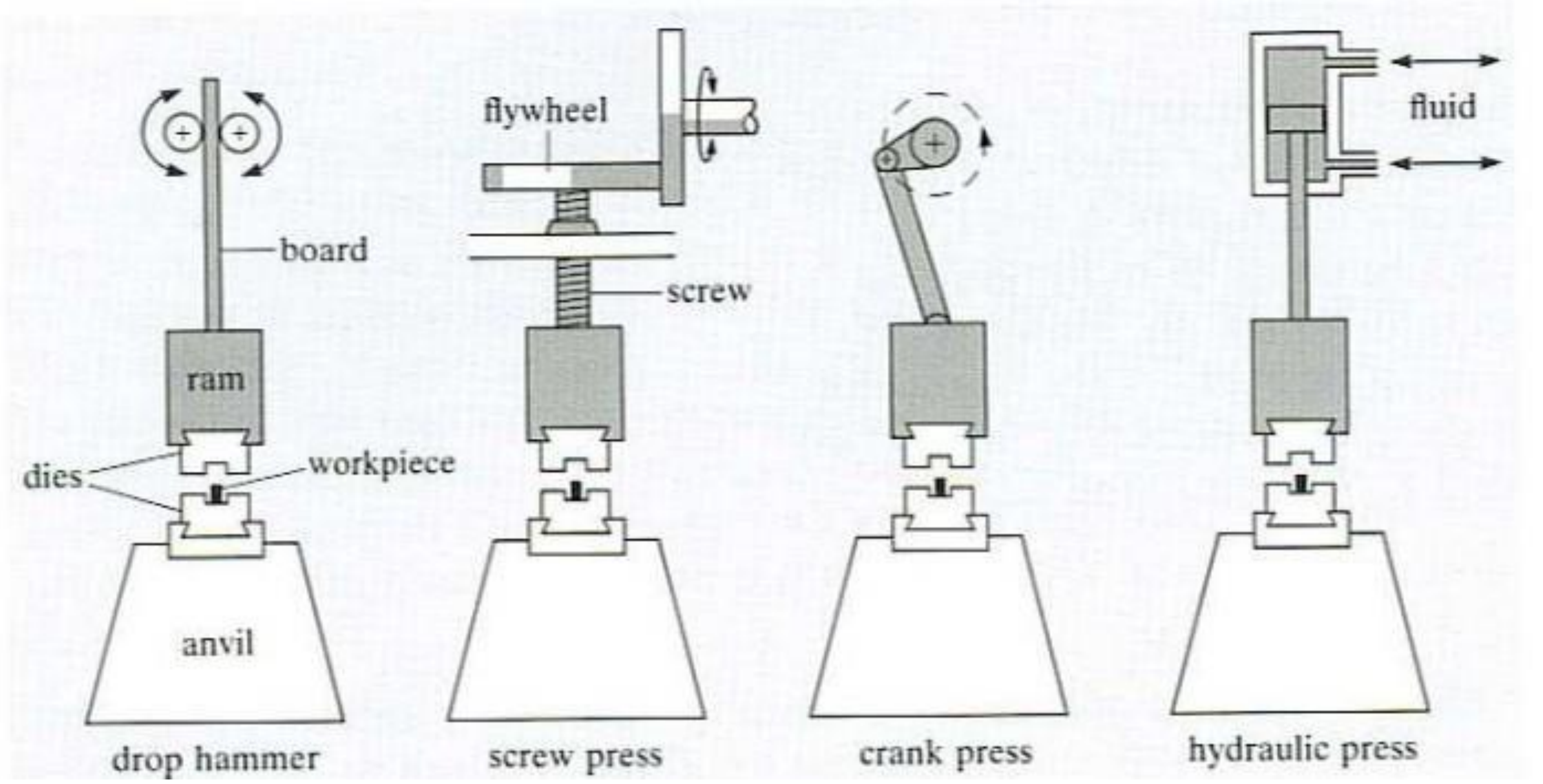


Table 3.3

Machine type	Load rating, F/kN	Available energy per blow, W/kJ	Ratio $W:F$ /m $\times 10^{-3}$
drop hammer	12 250	1.6	1.3
friction screw press	12 250	8.0	6.4
crank press	12 250	20	16
hydraulic press	12 250	250	200

HAMMER AND PRESS FORGING PROCESSES

Forging hammers

- There are two basic types of forging hammers used;
  - Board hammer
  - Power hammer

Forging presses

- There are two basic types of forging presses available;
  - Mechanical presses
  - Hydraulic presses

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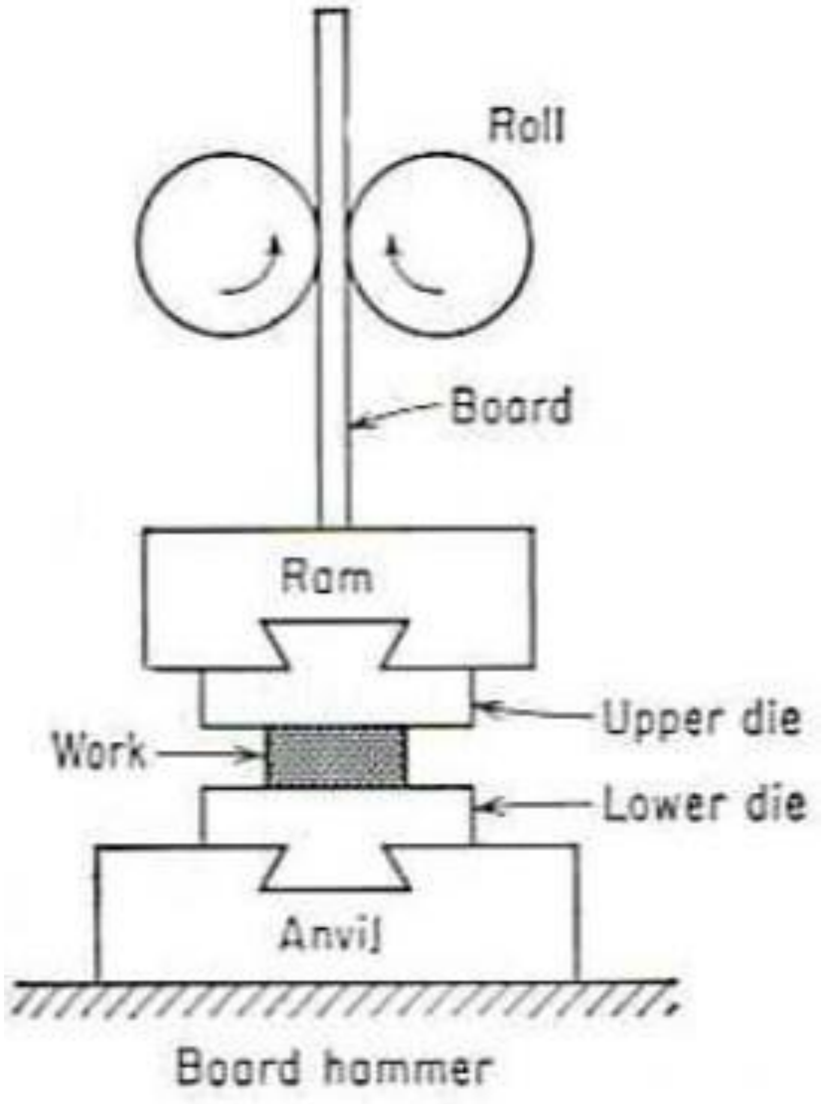
BOARD HAMMER -FORGING HAMMER

- The upper die and ram are raised by **friction rolls** gripping the board.
- After releasing the board, the ram falls under gravity to produce the **blow energy**.
- The hammer can strike between **60-150 blows** per minute depending on size and capacity.
- The board hammer is an energy-restricted machine. The blow energy supplied equal the **potential energy** due to the weight and the height of the fall.

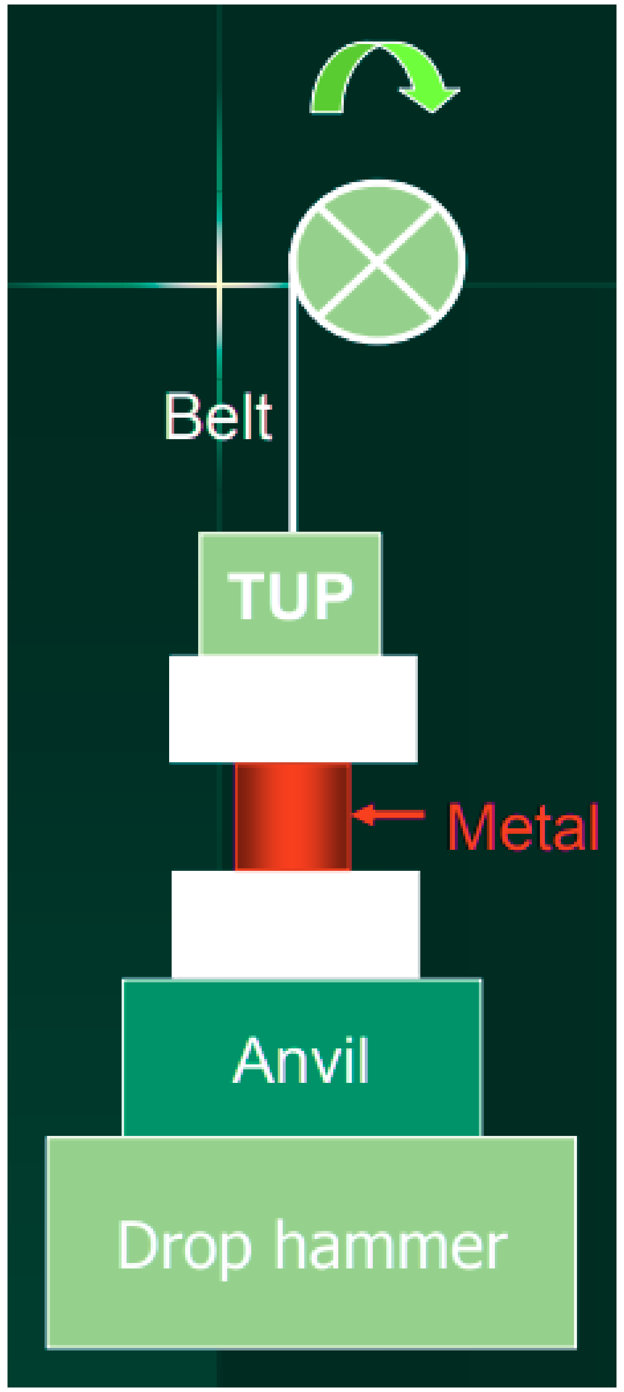


Potential energy = mgh ...*Eq 1*

- This energy will be delivered to the metal workpiece to produce plastic deformation.

FORGING HAMMER OR DROP HAMMER

- Provide rapid impact blows to the surface of the metal.
- Dies are in two halves
  - Lower : fixed to anvil
  - Upper : moves up and down with the TUP.
- Energy (from a gravity drop) is adsorbed onto the metal, in which the maximum impact is on the metal surface.
- Dies are expensive being accurately machined from special alloys (susceptible to thermal shock).
- **Drop forging** is good for mass production of complex shapes.



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ROLLING OF METALS

Objectives

- This chapter provides information on different types of metal rolling processes which can also be divided in to hot and cold rolling process.
- Mathematical approaches are introduced for the understanding of load calculation in rolling processes.
- Finally identification of defects occurring during and its solutions are included.

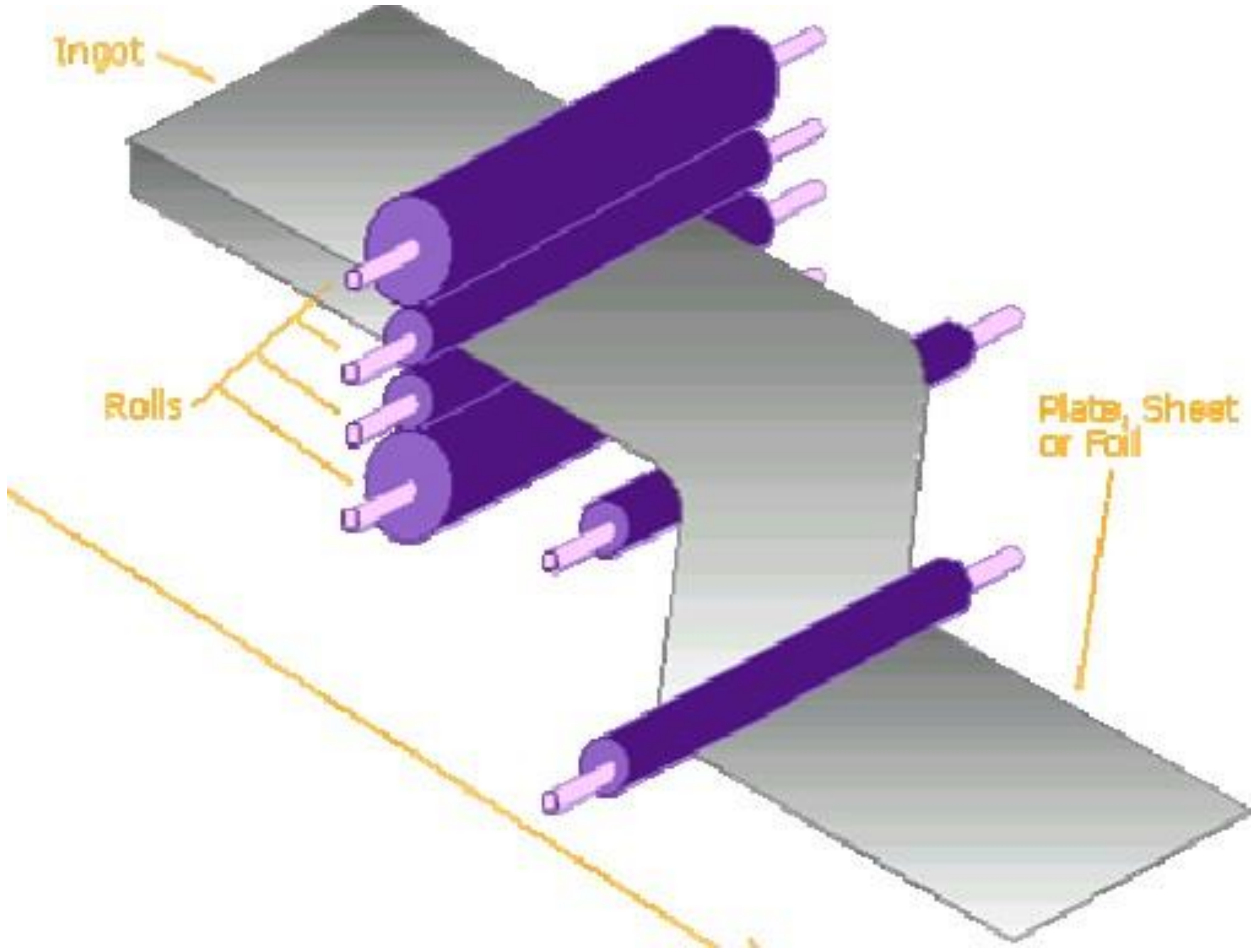
Introduction- Definition of rolling process

- **Definition of Rolling** :

The process of plastically deforming metal by passing it between rolls.

- Rolling is the most widely used production and close control of final product.

- The metal is subjected to high compressive stresses as a result of the friction between the rolls and the Rolling process metal surface.



Introduction- Hot and cold rolling processes

HOT ROLLING

The initial breakdown of ingots into blooms and billets is generally done by hot-rolling.
This is followed by further hotrolling into plate, sheet, rod, bar,pipe, rail.

COLD ROLLING

The cold-rolling of metals has played a major role in industry by providing sheet, strip, foil with good surface finishes and increased mechanical strength with close control of product dimensions.

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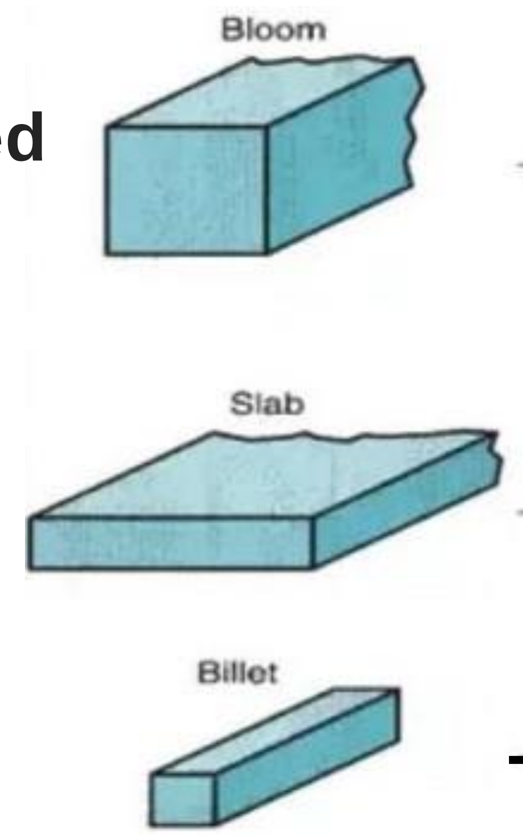
Terminology

Semifinished products

Further rolling steps

Mill products



.Bloom is the product of first breakdown of ingot
(cross sectional area > 230 cm2).

- Slab is the hot rolled ingot
(cross sectional area > 100 cm2 and with a width ≥ 2 x thickness).

- Billet is the product obtained from a further reduction by hot rolling
(cross sectional area > 40x40 mm2).

Sheet

- Sheet is the product with a thickness < 6 mm and width > 600 mm.

Strip

- Strip is the product with a thickness < 6 mm and width < 600 mm.

Plate

- Plate is the product with a thickness > 6 mm.

Rolliing mills

Rolling mill is a machine or a factory for shaping metal by passing it through rollers.

- Rolling mill basically consists of
- rolls.
- bearings.
- a housing for containing these parts.
- a drive (motor) for applying power to the rolls and controlling the speed.

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Different types of rolling processes:

There are different types of rolling processes as listed below;

- Continuous rolling
- Transverse rolling
- Shaped rolling or section rolling
- Ring rolling
- Powder rolling
- Continuous casting and hot rolling
- Thread rolling

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Craft Manufacturing

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Craft Manufacturing

Craft manufacturing refers to the process of producing goods or products by hand or using traditional methods, often in smaller quantities and with a focus on quality and craftsmanship. Unlike mass production, which relies heavily on automation and standardized processes, craft manufacturing involves skilled artisans who use their expertise to create unique or customized items.

Craft manufacturing can encompass a wide range of industries, including textiles, ceramics, woodworking, metalworking, and food production, among others. It often involves techniques that have been passed down through generations or are specific to certain cultural or regional traditions.

While craft manufacturing may not be as efficient or scalable as mass production methods, it often appeals to consumers who value authenticity, craftsmanship, and supporting local artisans or small businesses.

Additionally, craft manufacturing can contribute to the preservation of cultural heritage and traditional craftsmanship techniques

Craft Manufacturing

Craft manufacturing refers to the production of goods through manual or semi-automated processes in relatively small quantities. This type of manufacturing often involves skilled artisans or craftsmen who create products by hand or with the assistance of basic tools and machinery. Craft manufacturing is typically associated with artisanal goods that emphasize high quality, attention to detail, and unique designs.

Key characteristics of craft manufacturing include:

1. **Handcrafted Production**: Products are often made by skilled artisans who have expertise in their craft. Handcrafting allows for a high level of customization and attention to detail.
2. **Small Batch Production**: Craft manufacturers usually produce goods in small batches rather than mass-producing items on a large scale. This allows for greater flexibility and customization according to customer preferences.
3. **Quality and Authenticity**: Craft manufacturers prioritize quality over quantity. They often use high-quality materials and traditional techniques to create authentic products with unique characteristics.

Craft Manufacturing

Artistic Design: Craft manufacturing emphasizes artistic design and craftsmanship. Products may feature intricate designs, artistic flourishes, and personalized touches that set them apart from mass-produced goods.

1. **Local and Sustainable Practices**: Many craft manufacturers operate on a smaller scale and prioritize sustainable practices. They may source materials locally, minimize waste, and prioritize environmentally-friendly production methods.
2. **Direct Customer Engagement**: Craft manufacturers often have direct interactions with their customers, whether through artisan markets, online platforms, or boutique stores. This allows for a closer connection between the maker and the consumer, fostering a sense of community and appreciation for the craft.

Examples of craft manufacturing include handmade pottery, artisanal furniture, bespoke clothing, handcrafted jewelry, and artisanal food products such as cheeses, chocolates, and baked goods. While craft manufacturing may not be as efficient or cost-effective as mass production methods, it offers a level of quality, authenticity, and creativity that appeals to many consumers who value craftsmanship and individuality.

Hand's project

Casting Technology

Casting of bronze chandelier

1. Design
2. Craft details

Casting of metal sculptures

1. Bronze alloy
2. Craft details

Casting of metallic jewelry

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Hand's project

Casting of bronze chandelier

The chandelier is a signature of lighting design and has been one throughout the years, but its history goes back even further than people may think. Over the centuries, the chandelier has evolved, taken on new designs, spread all over the world and gone from holding candles to electric light bulbs, but the main idea of a marvelous centerpiece of lighting remains. This look at the multifaceted history of the chandelier is not exhaustive, but does cover many periods of time and how people lit their spaces in each one.

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Chandelier Design

1 Shaded
2 Crystal Chandelier
3 Candle-Style Chandelier
4 Mini-Small Chandelier
5 Drum Chandelier
6 Sputnik Chandelier
7 Empire Chandelier
8 Waterfall Chandelier
9 Center Bowl
10 Island
11 Globe
12 Cage (Home Depot)

Ex: Empire Chandelier

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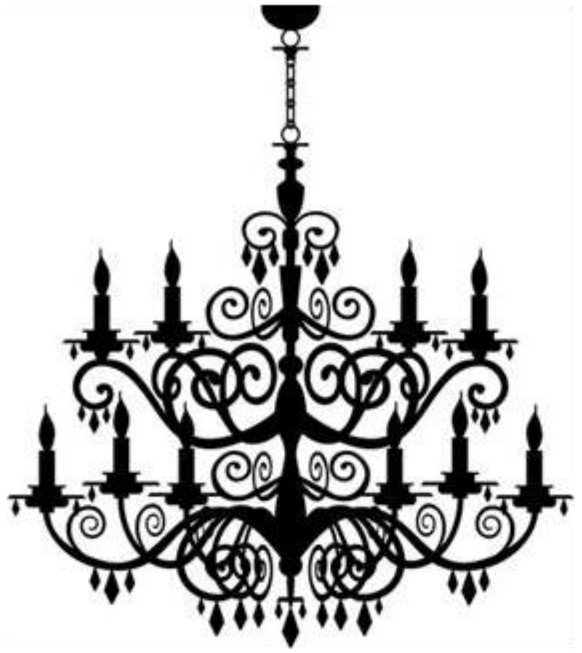
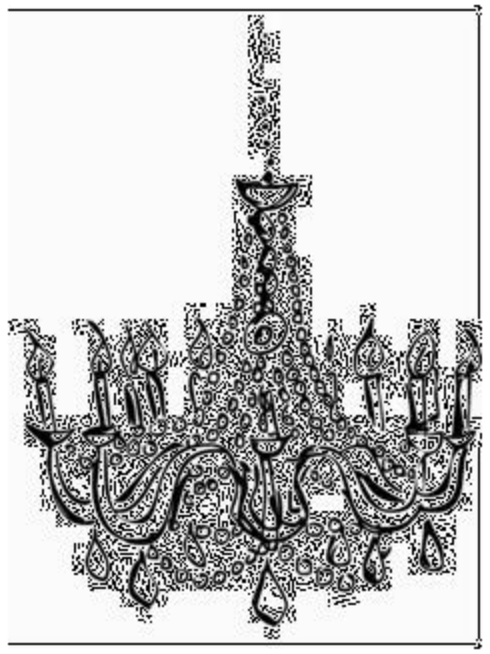
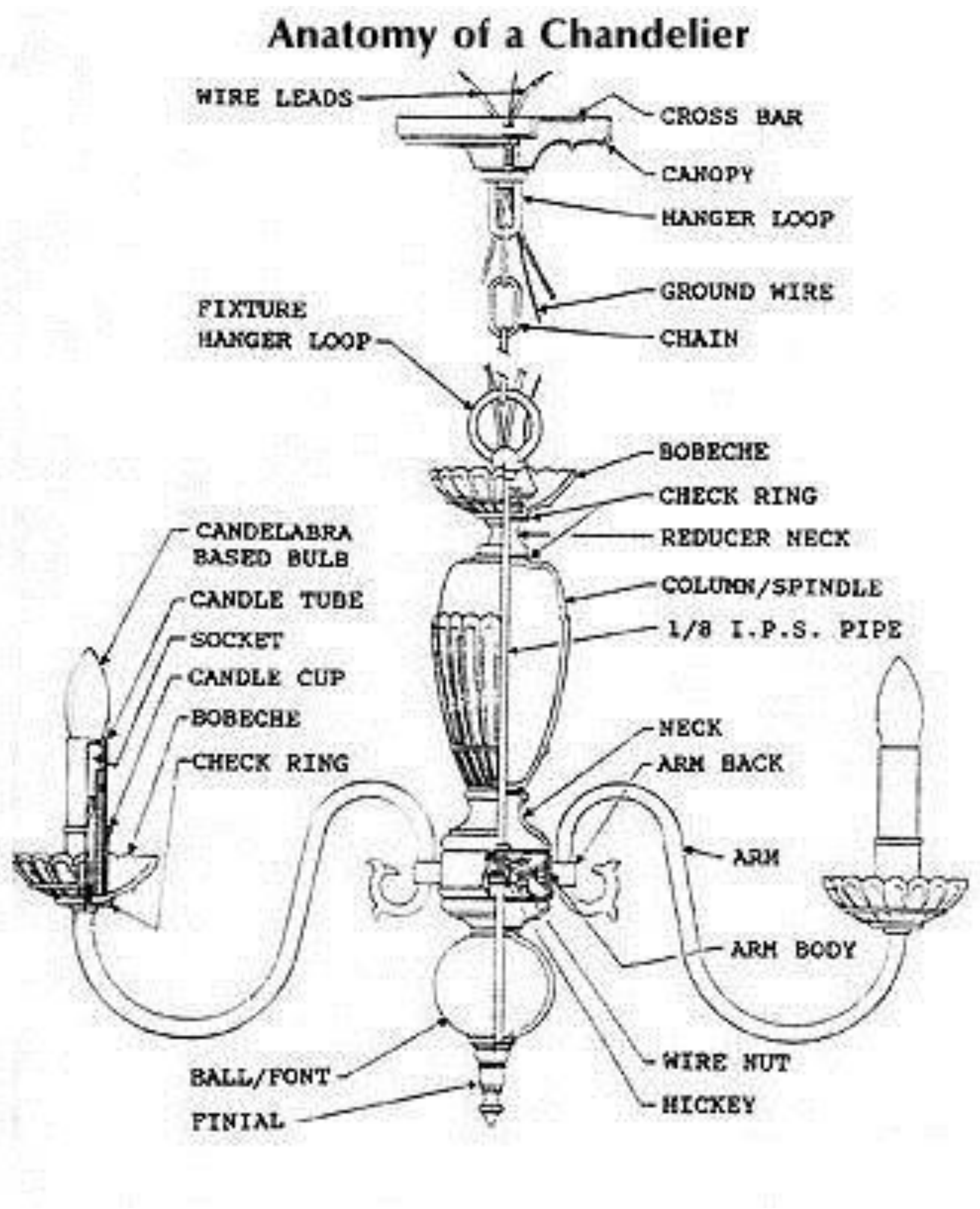
Some design types





Hand’s project

Chandelier parts names



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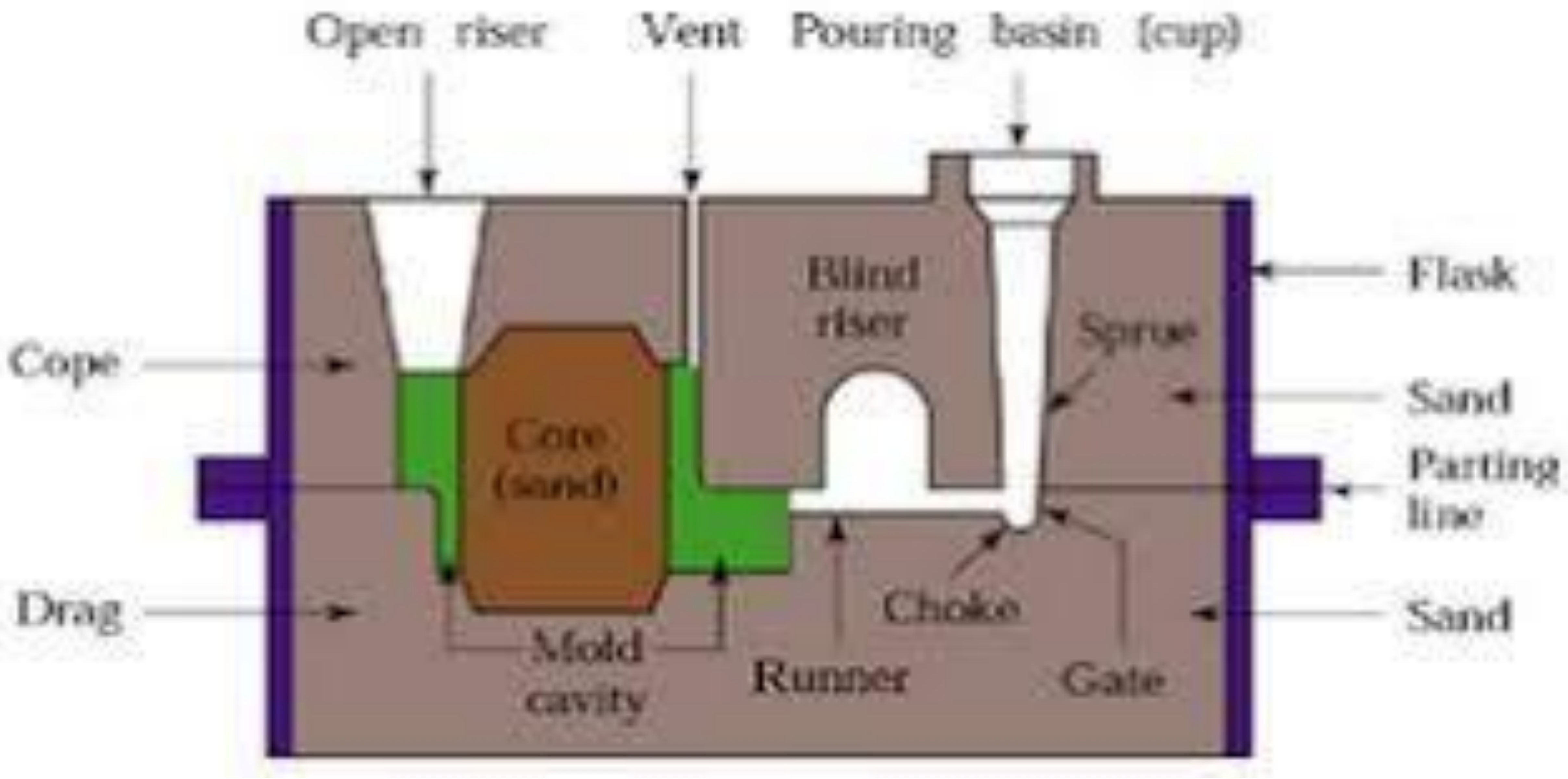
Sand Casting Process



Hand’s project

Hand’s project

Sand mould forming

Chandelier Casted Parts

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Assembling the chandelier

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Casting of metal sculptures

Bronze is the most popular metal for cast metal sculptures; a cast **bronze sculpture** is often called simply a "bronze". It can be used for statues, singly or in groups, reliefs, and small statuettes and figurines, as well as bronze elements to be fitted to other objects such as furniture. It is often gilded to give gilt-bronze or ormolu.

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Bronze Alloy

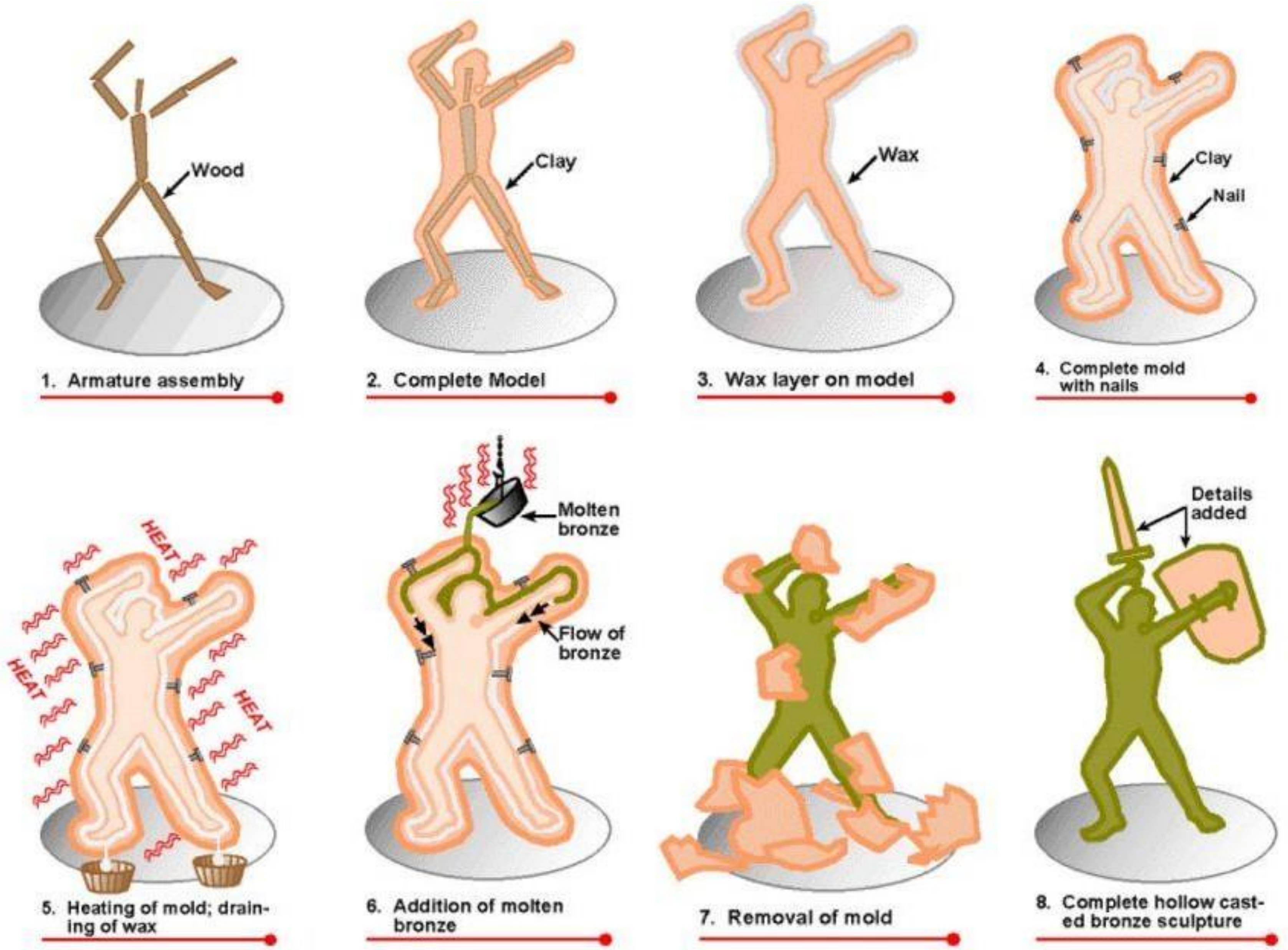
Bronze is an alloy consisting primarily of **copper**, commonly with **about 12–12.5% tin** and often with the addition of other metals (such as aluminium, manganese, nickel or zinc) and sometimes non-metals or metalloids such as arsenic, phosphorus or silicon. These additions produce a range of alloys that may be harder than copper alone, or have other useful properties, such as stiffness, ductility, or machinability.

Hand's project

Craft details

Bronze sculpture made by **lost wax process**

Lost-wax casting (also called "investment casting", "precision casting", or ***cire perdue*** which has been adopted into English from the French) is the process by which a duplicate metal sculpture (often silver, gold, brass or bronze) is cast from an original sculpture. Intricate works can be achieved by this method.



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Craft details

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Craft details

Casting of Metallic Jewellery

Hand’s project

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CNC Router

Definition

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How do we measure the world?

A computer numerical control (CNC) router is a computer-controlled cutting machine which typically mounts a hand-held router as a spindle which is used for cutting various materials, such as wood, composites, metals, plastics, glass, and foams. CNC routers can perform the tasks of many carpentry shop machines such as the panel saw, the spindle moulder, and the boring machine. They can also cut joinery such as mortises and tenons.

A CNC router is very similar in concept to a CNC milling machine. Instead of routing by hand, tool paths are controlled via computer numerical control. The CNC router is one of many kinds of tools that have CNC variants.

CNC Machines

Equipment limitations:

Overall material thickness cannot exceed the height of the machining bit above the support surface. The machining bit MUST be able to travel above the raw stock to work correctly. The vacuum attachment, when equipped, reduces this capacity significantly.

With the vacuum attachment and wooden base plate, the max cutting thickness is about 0.3 inches. With the vacuum attachment and wooden base plate removed, the maximum workpiece thickness is 2 inches, as limited by the z axis travel ability.

- This G-code interpreter and the equipment are capable of true three dimensional machining, BUT, the student version of HSMX press (G-code builder), does not allow beyond 2 and ½ dimensional machining without buying the full version. For the author's purpose, this is a limitation.

- This router is designed to machine NONMETALS ONLY. Engraving can be performed on plastics and soft metals. The exception to this is cutting electronic circuit boards PCB, in which an end mill can be used to machine the copper traces.

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Equipment :

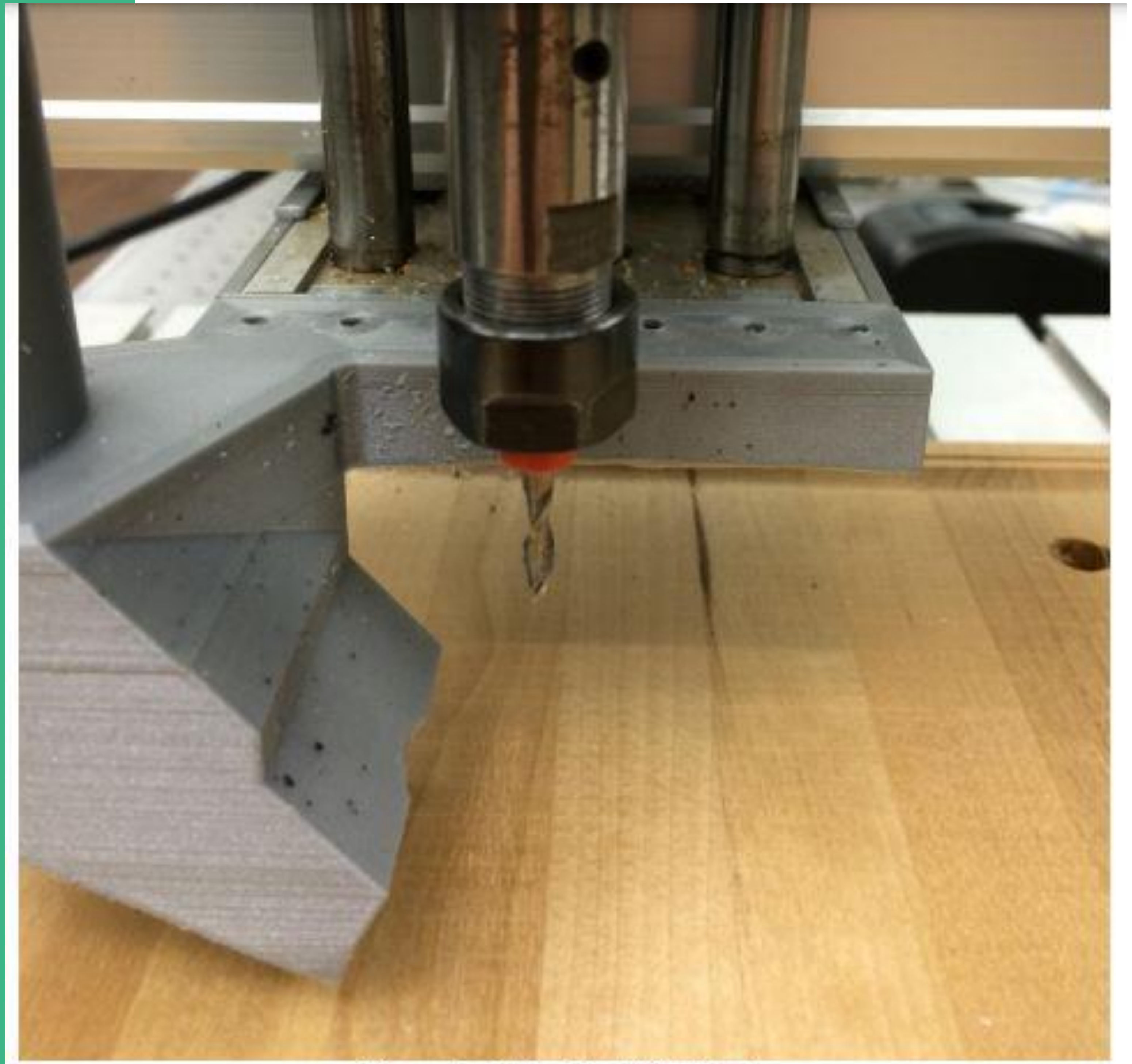
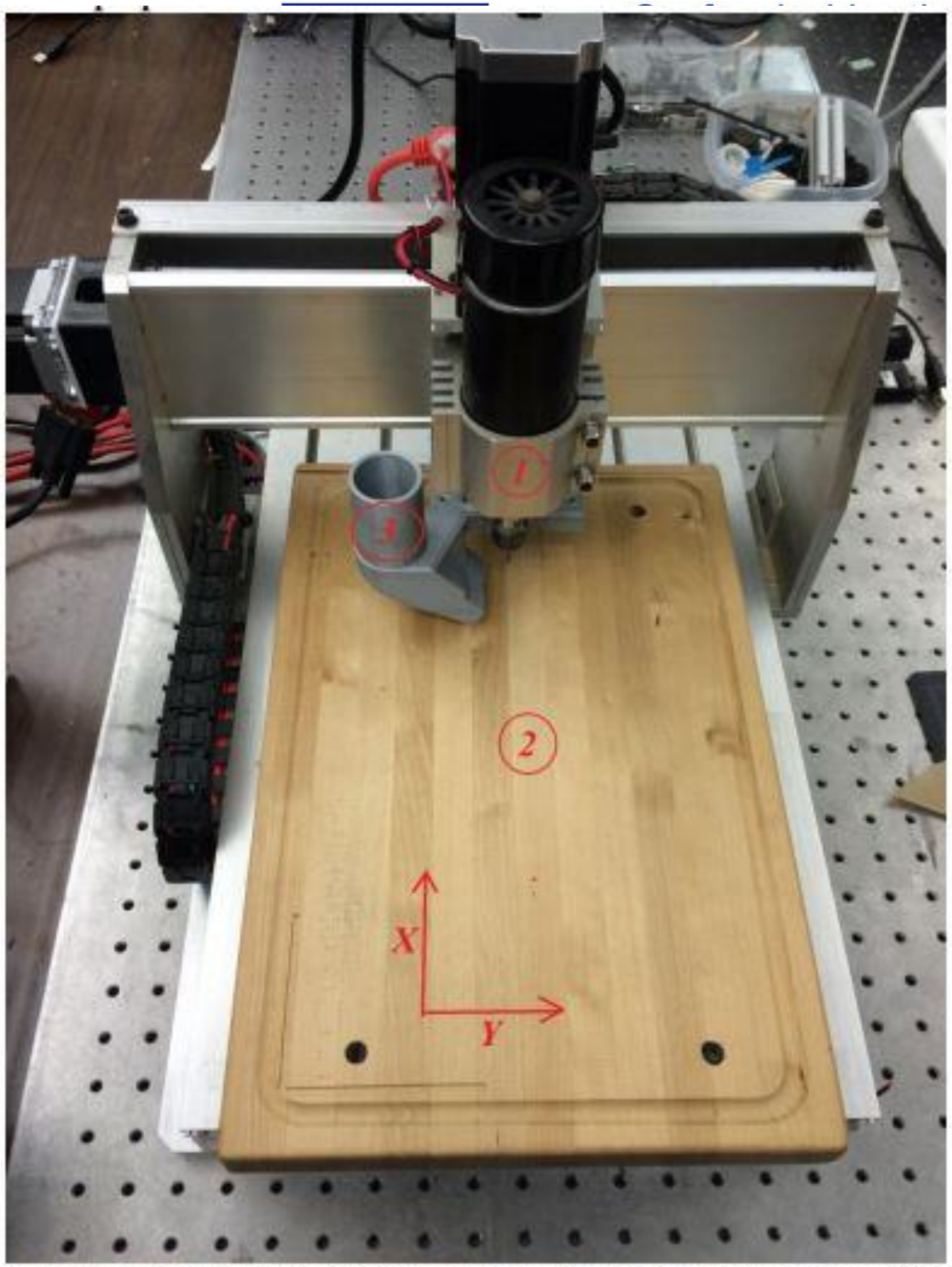


Figure 2: Cutting Head/Bit Chuck.



tting Motor, (2) Cutting Base, (3) Vacuum Attachment.

CNC Machines

Machine uses

A CNC wood router is a computer-controlled router tool that carves/etches objects or images into the face of a piece of wood.[1] The CNC Router is ideal for hobbies, engineering prototyping, product development, art, and production works. The CNC works on the Cartesian coordinate system (X, Y, Z) for 3D motion control; however, typical CNC operated systems can only make carvings on flat planes. The machine sits on a track and is not capable of making round or spherical cuts. Parts of a project can be designed in the computer with a CAD/CAM program, and then cut automatically using a router or other cutters to produce a finished part. In some instances, the table will not come with a router included. This allows the user to change out routers for different applications. For lighter strained cuts, they could use a lower grade router but for more intensive applications.

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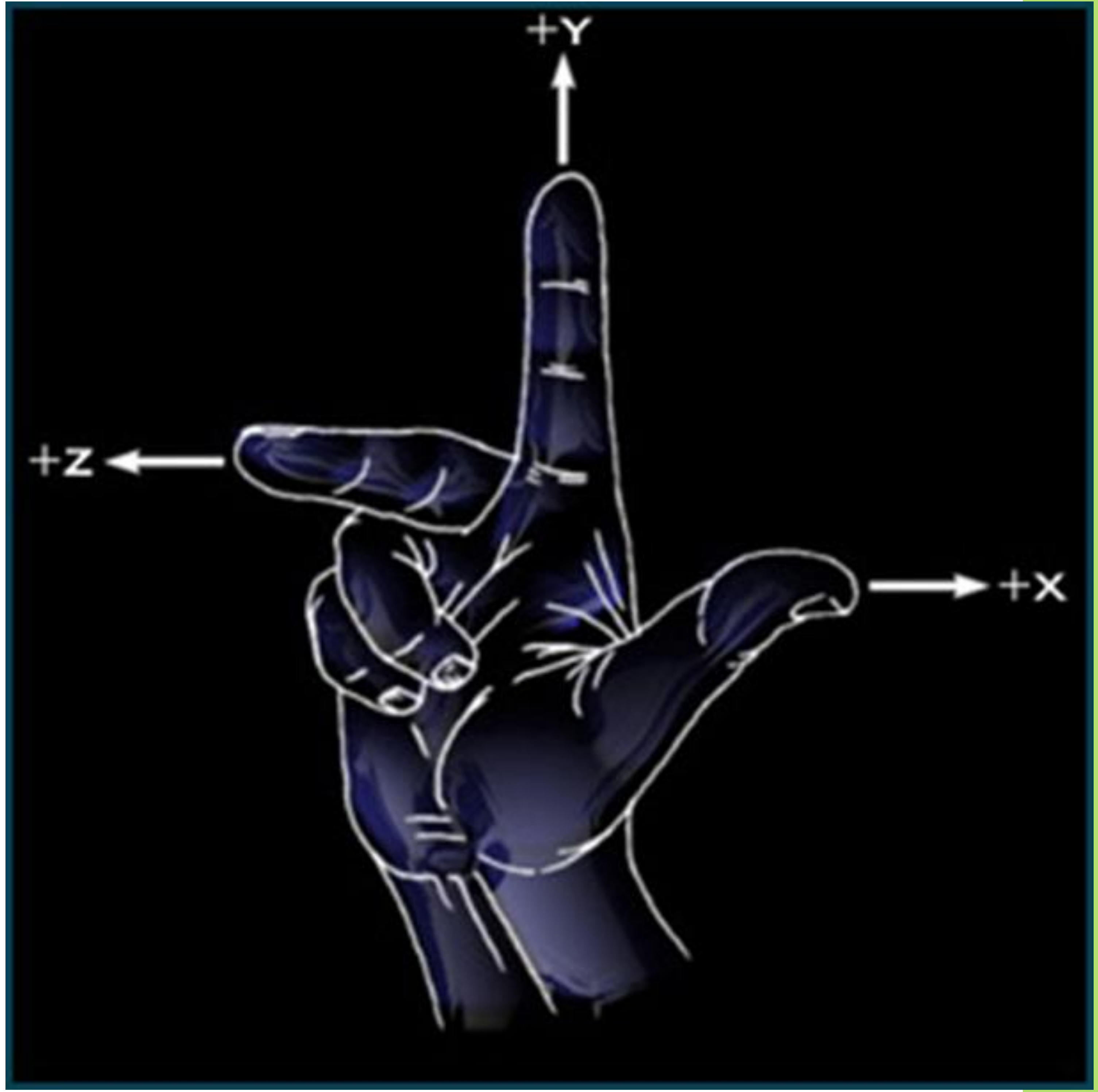
Machine coordinate system

- The direction of each finger represents the positive direction of motion.
- The axis of the main spindle is always Z, and the positive direction is into the spindle.
- On a mill the longest travel slide is designated the X axis and is always perpendicular to the Z axis.
- If you rotate your hand looking into your middle finger, the forefinger represents the Y axis.
- The base of your fingers is the start point or (X0, Y0, Z0).



CNC Machines

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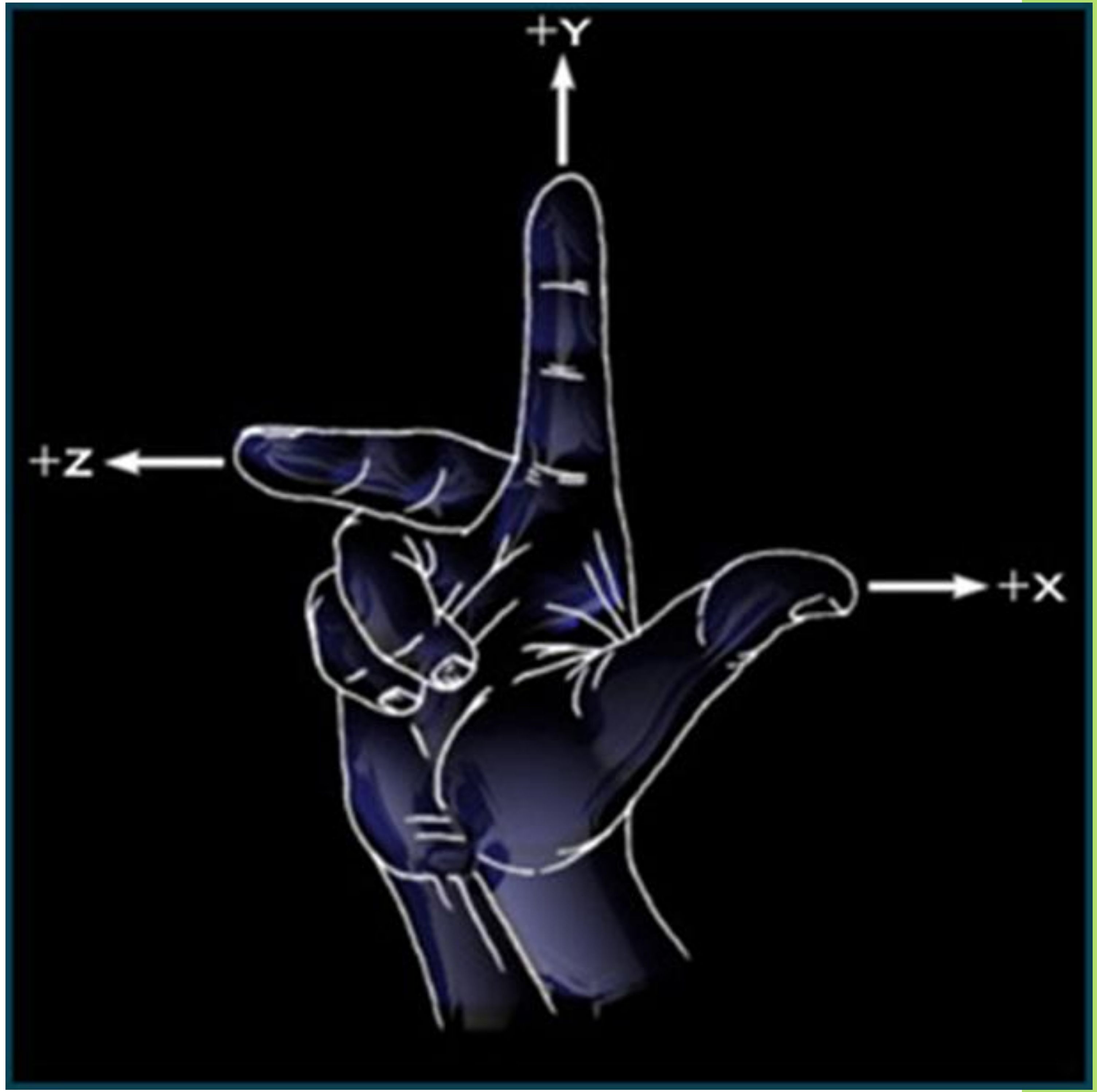

CNC Machines

Axis and motion nomenclature – Rotary motion designation

- The right-hand rule for determining the correct axis on a CNC machine may also be used to determine the clockwise rotary motion about X, Y, and Z.
- To determine the positive, or clockwise, direction about an axis, close your hand with the thumb pointing out.
- The thumb may represent the X, Y, or Z direction and the curl of the fingers may represent the clockwise, or positive, rotation about each axis.
- These are known as A, B, and C and represent the rotary motions about X, Y, and Z, respectively.

CNC Machines

How CNC Works

- Controlled by G and M codes.
- These are number values and co-ordinates.
- Each number or code is assigned to a particular operation.
- Typed in manually to CAD by machine operators.
- G&M codes are automatically generated by the computer software.

CNC Machines

Features of CNC Machinery

- The tool or material moves.
- Tools can operate in 1-5 axes.
- Larger machines have a machine control unit (MCU) which manages operations.
- Movement is controlled by a motors (actuators).
- Feedback is provided by sensors (transducers)
- Tool magazines are used to change tools automatically.

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CNC Programming Basics

- CNC instructions are called part program commands.
- When running, a part program is interpreted one command line at a time until all lines are completed.
- Commands, which are also referred to as blocks, are made up of words which each begin with a letter address and end with a numerical value.
- Each letter address relates to a specific machine function. “G” and “M” letter addresses are two of the most common. A “G” letter specifies certain machine preparations such as inch or metric modes, or absolutes versus incremental modes.
- A “M” letter specifies miscellaneous machine functions and work like on/off switches for coolant flow, tool changing, or spindle rotation. Other letter addresses are used to direct a wide variety of other machine commands.

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CAD/CAM

- Two computer-based systems which impact the use of CNC technology are computer aided design and computer aided manufacturing.
- A computer aided design, or CAD, system uses computers to graphically create product designs and models. These designs can be reviewed, revised, and refined for optimum end use and application. Once finalized, the CAD design is then exported to a computer aided manufacturing, or CAM, system.
- CAM systems assist in all phases of manufacturing a product, including process planning, production planning, machining, scheduling, management and quality control.

CNC Machines

G Code

Building the G-Code (Cut Paths)

About the Interpreter:

The G-code interpreter used in this tutorial is the student version of HSMXpress (free), by Autodesk. It is purely a SolidWorks add-on and CANNOT function by itself. However, it is not the only G-code interpreter available. Please note that assistance cannot be provided with any other interpreter.

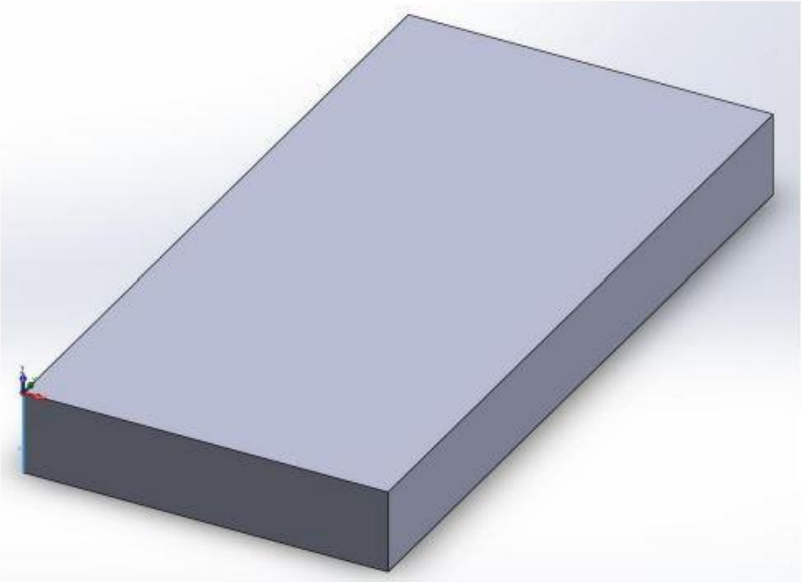
Figure 4: Adding a Reference Coordinate System

Before you begin you will need:

- A completed SolidWorks part file.
- A computer equipped with SolidWorks and the HSMXpress software.

Process Steps:

1. Load the part file in SolidWorks and initialize the HSMXpress add-in.
2. Begin by inserting a reference geometry coordinate system on the SolidWorks part. This coordinate system will represent the 0,0,0 (start position) of the CNC router. This coordinate system should be inserted such that the positive Z axis is vertical, parallel with the direction of the cutting bit; The positive X axis is to the right; and the positive Y axis is up, along the length of the part. See Figure 4.

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G Code

3. Create a new job in HSMXpress by clicking the “CAM” tab in SolidWorks. Navigate to the CAM tab in the left hand side bar, right click, and select “New Job”. Select “Relative Size Box” and “No Additional Stock” under the Stock section. Select “Use Coordinate System” and select the coordinate system added in step 2 below the drop down menu. Click new machine and define the speeds and workpiece limitations as listed in step 4.

Click the green arrow to complete the new job. Any cutting operations created under this new job will use the speeds and limitations defined in this menu.

4. Review the HSMXpress tutorials and build your cut path accordingly.

Note: Transit (non-cutting) speeds should not exceed 70 inches per minute. Plunge (drill) peeds should not exceed 6 inches per minute. Lateral cutting speeds should not exceed 60 inches per minute. These speeds are the absolute maximums and will vary according to the material being cut and the depth of cut. For softer plastics, the cutting speed will be very near the listed maximums. For harder plastics and softer metals (engraving only), the speeds will be a lot slower. Recommended cutting speeds for PCB electrical traces with a 1/16 inch diameter end mill are as follows: Lateral cut, 6 inches/min, plunge cut, 1 inch per min.

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G Code

Note: Cutting speeds can be changed real time in the Mach 3 G-code interpreter, so values entered in the HSMXpress can be considered “ball park” figures.

Note: Cutting should be performed at incremental depths. The depth steps should be between 0.005 and 0.050 inches per step. Do not attempt to cut anything thicker than 0.050 inches in a single cut. When using a 1/16 inch diameter end mill, NEVER exceed 0.010 inches per depth step, or you may break the end mill.

Note: Be sure to select the appropriate cutting tool for each operation. The selected “Coolant method” should always be “Flood”. Selecting any other coolant method may result in an interpreter error.

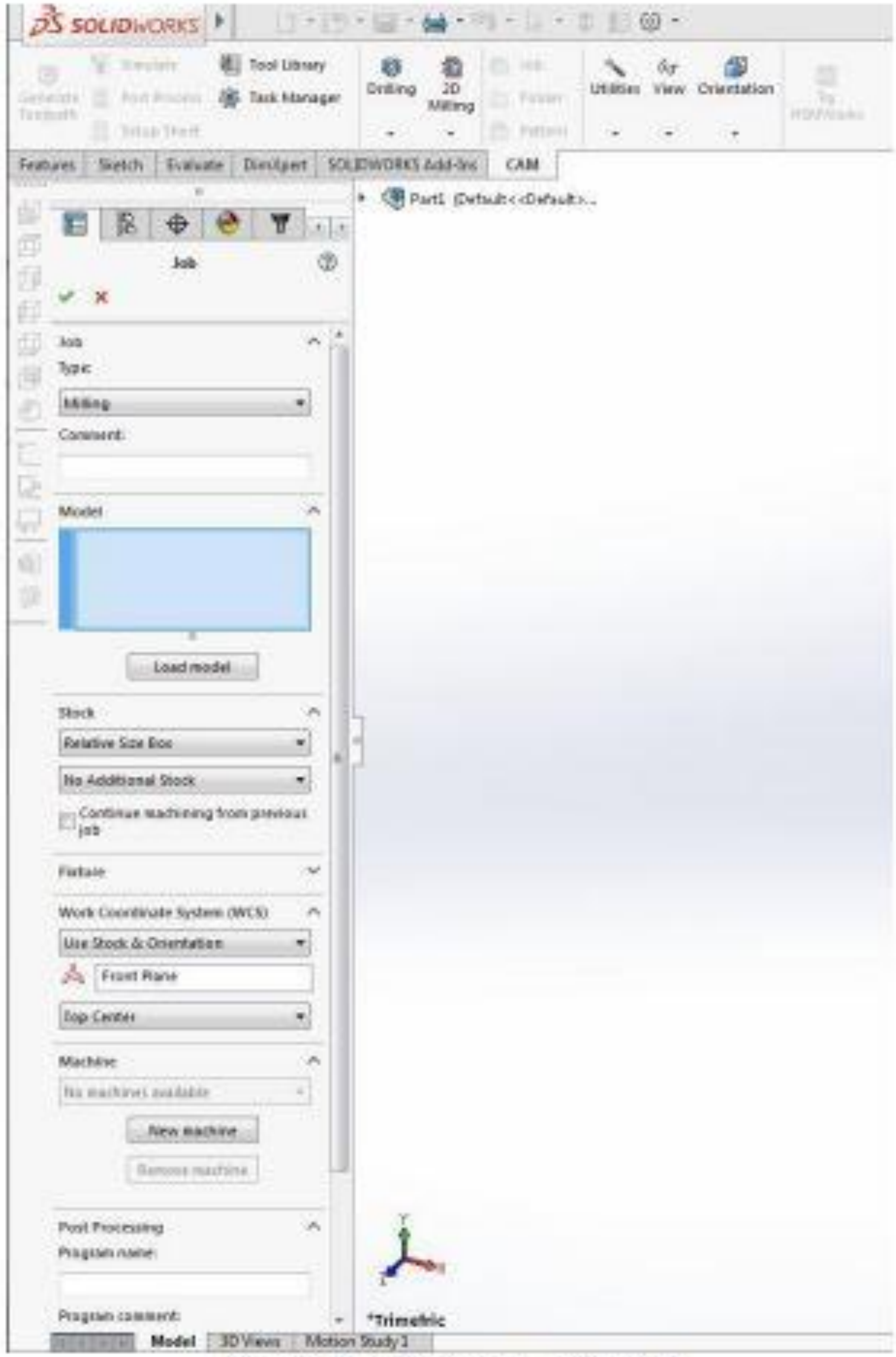


Figure 5: HSMXpress, New Job

CNC Machines

G Code

5. Simulate your cut paths by selecting the created cutting operations and clicking “Simulate” under the CAM tab. It will provide you graphical simulation of the cuts, as well as provide an estimated completion time. The purpose of this step is to verify that the cuts will accomplish what is desired.

6. Once your cut paths are to your satisfaction, click “Post Process” in the CNC tab to open the G-code compiler.

7. In the Post Process compiler, select “mach3mill.cps – Generic Mach3Mill” in the “Post Configuration” drop down menu. This is IMPORTANT. Not doing so will create G-code that may be wholly unusable by the Mach 3 G-code interpreter. Define a file output name and destination. When complete, click the “Post” button.

8. Navigate on your computer to the destination folder that you selected in step 7. Open your file using any text editor. This is your G code file. We may need to make a few changes to make the operation work without erroneous cuts.

CNC Machines

G Code

a. First, scroll down to the first cutting operation, usually about 16 lines from the top. Look for a line starting with “G0”, followed by a line starting with “G43”. Switch these lines. The purpose of this is to make the router raise to transit height before moving to the initial start point. Not changing these will result in the router head being dragged along the surface of the material to the start point.

b. Second, scroll to the very end of the G-code file. Look for a line starting with “G28”. Change the z value listed in that line to the clearance height that you defined in your HSMXpress cut paths. For example, if you defined a 0.2” clearance height, change “G28 G91 Z0.” to “G28 G91 Z0.2”. This will cause the router to maintain the clearance height as it transits to the end position, rather than dragging across the workpiece at the zero height.

9. Save the G-code file as a text document, filetype .txt.

CNC Machines

CNC Machines- Advantages/Disadvantages

Advantages:

- High Repeatability and Precision e.g. Aircraft parts
- Volume of production is very high
- Complex contours/surfaces need to be machined. E.g. Turbines
- Flexibility in job change, automatic tool settings, less scrap
- More safe, higher productivity, better quality
- Less paper work, faster prototype production, reduction in lead times

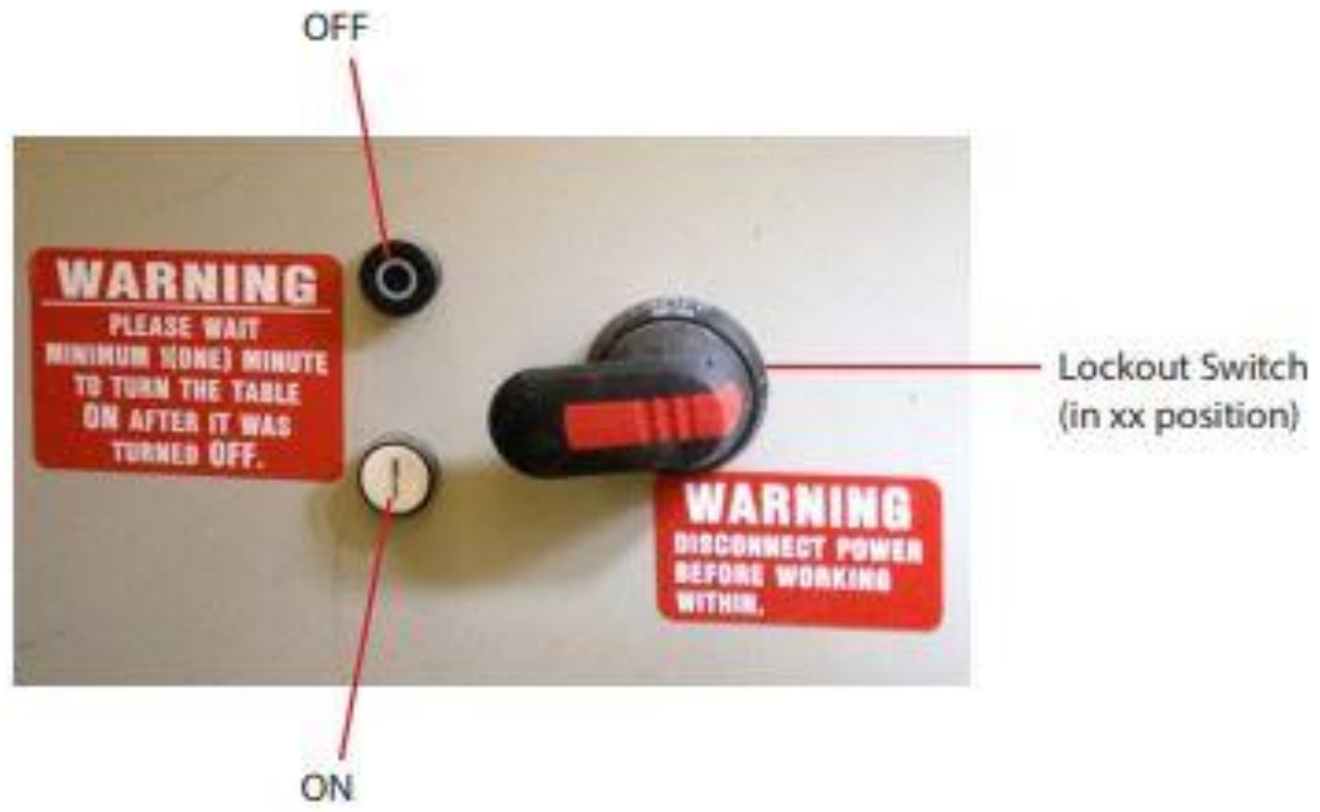
Disadvantages:

- Costly setup, skilled operators
- Computers, programming knowledge required
- Maintenance is difficult

CNC Machines

Starting to work

1. When preparing to use the CNC machine, carefully check each item listed on the previous page. Once you are ready, make an appointment with an instructor or TA.
2. If you have questions or need help preparing your file, consult one of the TAs
3. Make sure you have the proper safety equipment and training in the woodshop, including proper footwear and protective glasses.



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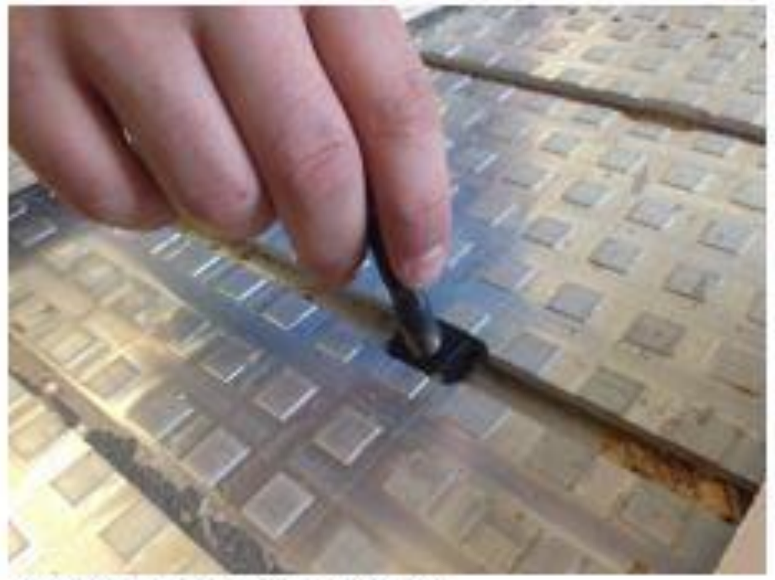
Lay waste strips under stock


Insert clamping bolts into slots


Position the clamp fingers with step blocks


Use washers to protect bolt thread (if necessary)


Keep the stock parallel to the table


Tighten the bolts to secure the stock

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INSTALL YOUR BIT

1. Prepare the tool holder fixture:

- Secure it in the nearest woodworking vise

- Use the plunger to lock it in a tool holder

2. Remove the existing collet:

- Use the spanner to remove the collet nut

- Push on one side of the collet to snap it out

- Notice how the groove in the collet is captured by the internal thread on the nut. This allows the nut to press the collet into the cone, and extract it from the cone.

3. Install the bit:

- Snap a 1/4” collet into the nut, and engage the nut with the holder

- NEVER put the collet into the holder unless it is snapped into a nut

- Insert the bit, so that as much of the shaft is in the collet as possible, but such that the helical grooves are fully exposed

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- Use the spanner to tighten the nut securely

4. Open the air valve on the dust-collector

5. Move the spindle to a convenient spot:

- Move the gantry to the left • 4 •

- Move the head towards you • 8 •

6. Mount the tool holder into the spindle:

- With your right hand, hold the tool holder into the spindle cone

- With your left hand, press the green button on the side of the spindle

CNC Machines

CLAMPING THE MATERIAL:

1. Place some waste strips on the table to support your stock. Make sure your completed part will also be supported when the cut is complete.
2. Find as many T-nuts as you'll need.
3. Select your clamping bolts. They must be long enough to accommodate the waste strips and the stock and to pass completely through the clamp nut, but NOT so long that the clamp nut bottoms out.
4. If necessary, add some washers to protect the bottom of the bolt thread.
5. Build a secure stack of step blocks just slightly higher than the waste strips and stock.
6. Place the clamp fingers so the bolt is close to the work, and the stepblocks are far from the bolt.
7. Use a combination square to keep your stock parallel to the long edge of the table.
8. Gradually tighten the clamp nuts, checking the alignment of the stock as you go.
9. Be sure NOT to have anything projecting into the path of the gantry.
10. At this point you should select the router bit for your project: no smaller than 1/4" diameter and no bigger than 3/8".

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Exercise 1

Build a table with a 7-piece with hard board, half-timbered assemblies, dowels, boxes, and wedges, with no need for glue or hardware for the final assembly.

Use AutoCAD or CAD CAM.

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Exercise 2

Joinery Box: Design and construct a small box using different joinery techniques such as dovetail, finger joints, or box joints.

Use AutoCAD or CAD CAM.

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THANK YOU!