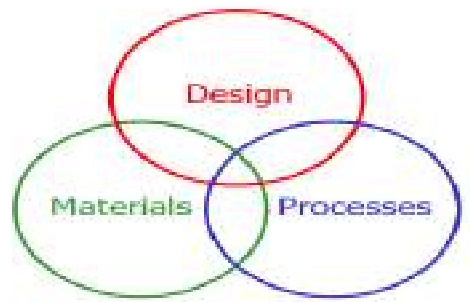
ME 1302 - Principles of manufacturing process (3-2-1-2)

Manufacturing Processes

Manufacturing processes are the steps through which raw materials are transformed into a final product. The manufacturing process begins with the creation of the materials from which the design is made. These materials are then modified through manufacturing processes to become the required part. Manufacturing processes can include treating (such as heat treating or coating), machining, or reshaping the material. The manufacturing process also includes tests and checks for quality assurance during or after the manufacturing, and planning the production process prior to manufacturing.



Course Topics

1. Engineering materials
2. introduction to entrepreneurship,
3. Manufacturing processes: casting, welding, forming, working , joining processes.
4. Hand work and hand tools,
5. Concept of machining processes, turning, drilling milling, and grinding.
6. Metrological concepts.
7. Industrial safety.
8. Laboratory experiments.

Program and Course Outcomes:

1. To understand the principle of manufacturing engineering
2. To obtain important information about the iron ores and how can obtain the different types of iron and steel
3. To classify materials and their improvement properties
4. To know the different types of machining processes
5. To obtain an ability to identify, formulate and solve problems of machining
6. To gain important information about sand casting and different types of welding processes.

Recommended Textbook(s):

1. Fundamentals of Modern Manufacturing by Groover.
2. Manufacturing Engineering and Technology by Kalpakjian.

LEC-2

Extraction of metals and materials.

We study iron Extraction as example of this title

Iron Ores

- Almost all industrial Iron making worldwide is based around iron oxide ores
- Iron is the fourth most abundant element on the Earth's crust

- Generally require Fe content of >58 wt % for economical BF process (The blast furnace is a reactor which produces an impure form of molten iron).

1-Crushing and grinding of the ore : These ores occur in nature as huge lumps. They are broken to small pieces with the help of *crushers or grinders*. These pieces are then reduced to fine powder with the help of a ***ball mill or stamp mill.*** This process is called ***pulverisation.*** السحق

2- CONCENTRATE THE ORE: Depending upon the nature of the ore, one or more of the following steps are taken to concentrate the ore. These are mostly physical methods of concentration.التركيز

A))Magnetic separation – Magnetic ores like pyrolusite (MnO_2) and chromite ($FeO.Cr_2O_3$)are enriched by this method by making use of the difference in the magnetic properties of the ore and gangue particles. The powdered ore is dropped on to leather or brass conveyer belt, which moves over two rollers one of which is magnetic. When the ore passes over the magnetic roller, it sticks to the belt due to the force of attraction and falls nearer to magnetic roller. The gangue falls in a normal way under the

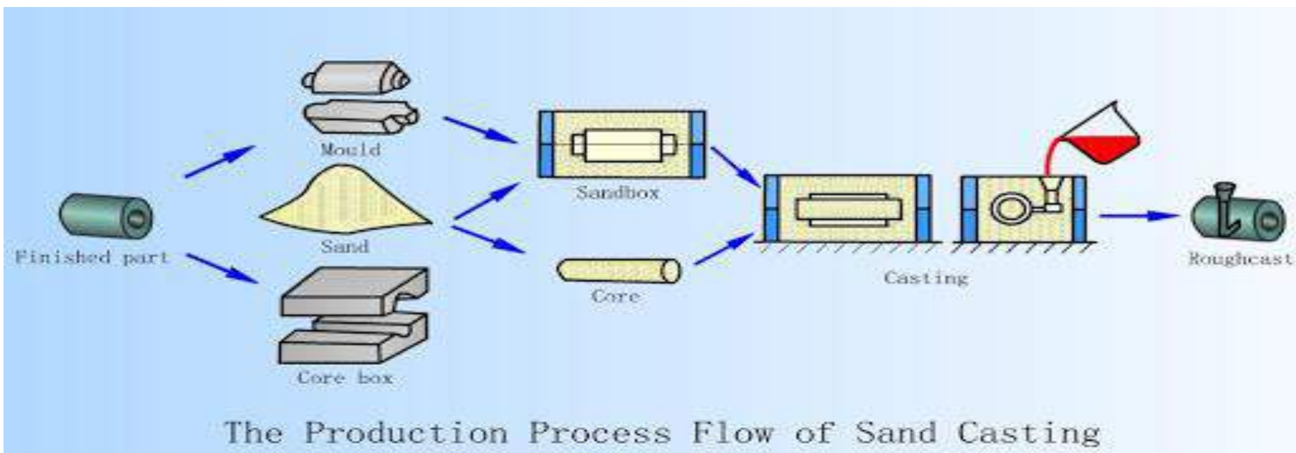
FUNDAMENTALS OF METAL CASTING

Solidification Processes

https://www.youtube.com/watch?v=pwaXCko_Tkw

Casting

casting is a process in which a liquid metal is somehow delivered into a mold that contains a hollow cavity (i.e., a 3-dimensional negative image) of the intended shape. The metal and mold are then cooled, and the metal part (the *casting*) is extracted. Casting is most often used for making complex shapes that would be difficult or uneconomical to make by other methods.



Advantages

- (Can create complex part geometries that can not be made by any other process
  - Can create both external and internal shapes
  - Some casting processes are *net shape;* others are *near net shape*
  - Can produce very large parts (with weight more than 100 tons), like m/c bed
  - Casting can be applied to shape any metal that can melt
  - Some casting methods are suited to mass production
  - Can also be applied on polymers and ceramics

Disadvantages

- Different disadvantages for different casting processes:
- Limitations on mechanical properties
- Poor dimensional accuracy and surface finish for some processes; e.g., sand casting

FUNDAMENTALS OF METAL CASTING

Solidification Processes

Die Casting: -

Die casting is a metal casting process that is characterized by forcing molten metal under high pressure into a mold cavity. The mold cavity is created using two hardened tool steel dies which have been machined into shape and work similarly to an injection mold during the process. Most die castings are made from non-ferrous metals, specifically zinc, copper, aluminum, magnesium, lead, pewter and tin-based alloys. Depending on the type of metal being cast, a hot- or cold-chamber machine is used.

The casting equipment and the metal dies represent large capital costs and this tends to limit the process to high-volume production. Manufacture of parts using die casting is relatively simple, involving only four main steps, which keeps the incremental cost per item low. It is especially suited for a large quantity of small- to medium-sized castings, which is why die casting produces more castings than any other casting process. Die castings are characterized by a very good surface finish (by casting standards) and dimensional consistency.

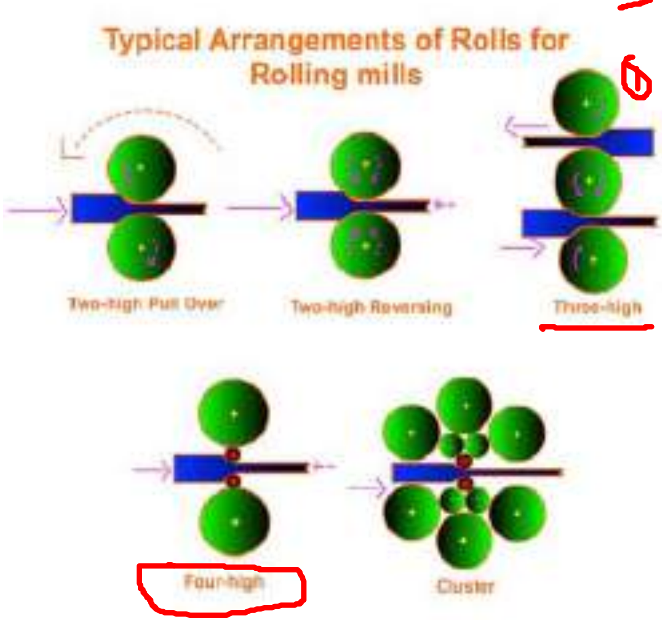
1. Rolling: -

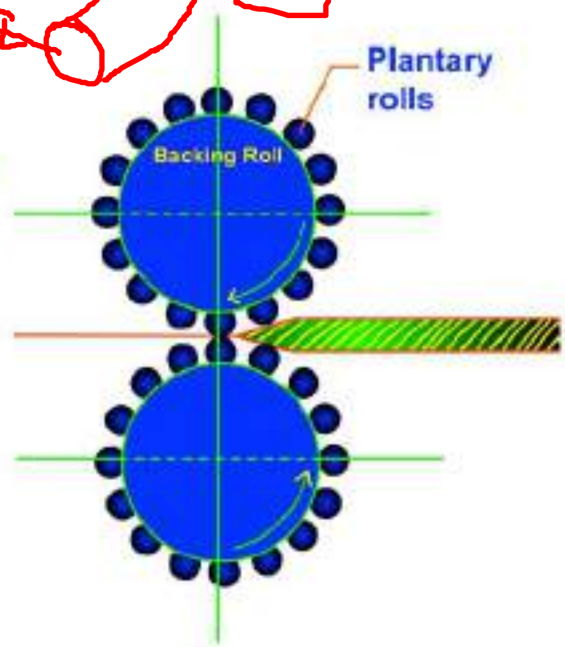
Introduction

Rolling is one of the most important industrial metal forming operations. Hot Rolling is employed for breaking the ingots down into wrought products such as into blooms and billets, which are subsequently rolled to other products like plates, sheets etc. Rolling is the plastic deformation of materials caused by compressive force applied through a set of rolls. The cross section of the work piece is reduced by the process. The material gets squeezed between a pair of rolls, as a result of which the thickness gets reduced and the length gets increased. Mostly, rolling is done at high temperature, called hot rolling because of requirement of large deformations.

2 Rolling mills:

Rolling mill consists of rolls, bearings to support the rolls, gear box, motor, speed control devices, hydraulic systems etc. The basic type of rolling mill is two high rolling mill. In this mill, two opposing rolls are used. The direction of rotation of the rolls can be changed in case of reversing mills, so that the work can be fed into the rolls from either direction. Such mills increase the productivity. Non reversing mills have rolls rotating in same direction. Therefore, the work piece cannot be fed from the other side. Typical roll diameters may be 1.4 m. A three high rolling mill has three rolls. First rolling in one direction takes place along one direction. Next the work is reversed in direction and fed through





Forging

Forging is the term for shaping metal by using localized compressive forces. **Cold forging** is done at room temperature or near room temperature. **Hot forging** is done at a high temperature, which makes metal easier to shape and less likely to fracture. **Warm forging** is done at intermediate temperature between room temperature and hot forging temperatures.

- 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.

Classification of forging processes:-

By equipment or mechanism

Forging hammer or drop hammer. It is the process that change the shape of the product by continual hammering in several directions to get to the final form or ship.

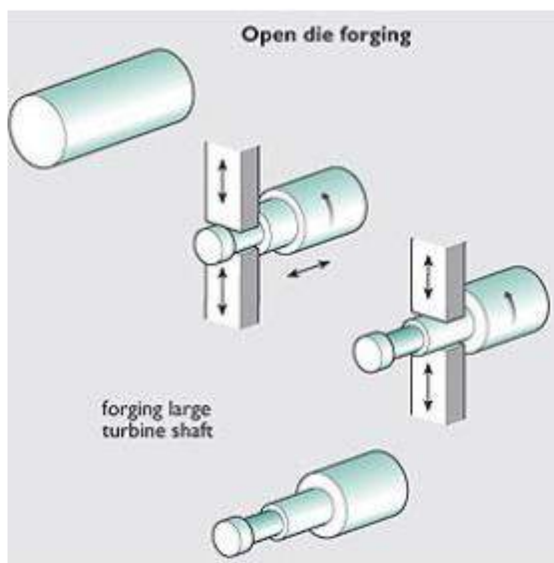
Press forging: It is scientific, which is done by changing the shape of the product by shedding constant pressure on the product at a fixed strain rate to get to the final form

By process

1) Open - die forging

2) Closed - die forging

Open-Die Forging



Open-Die Forging

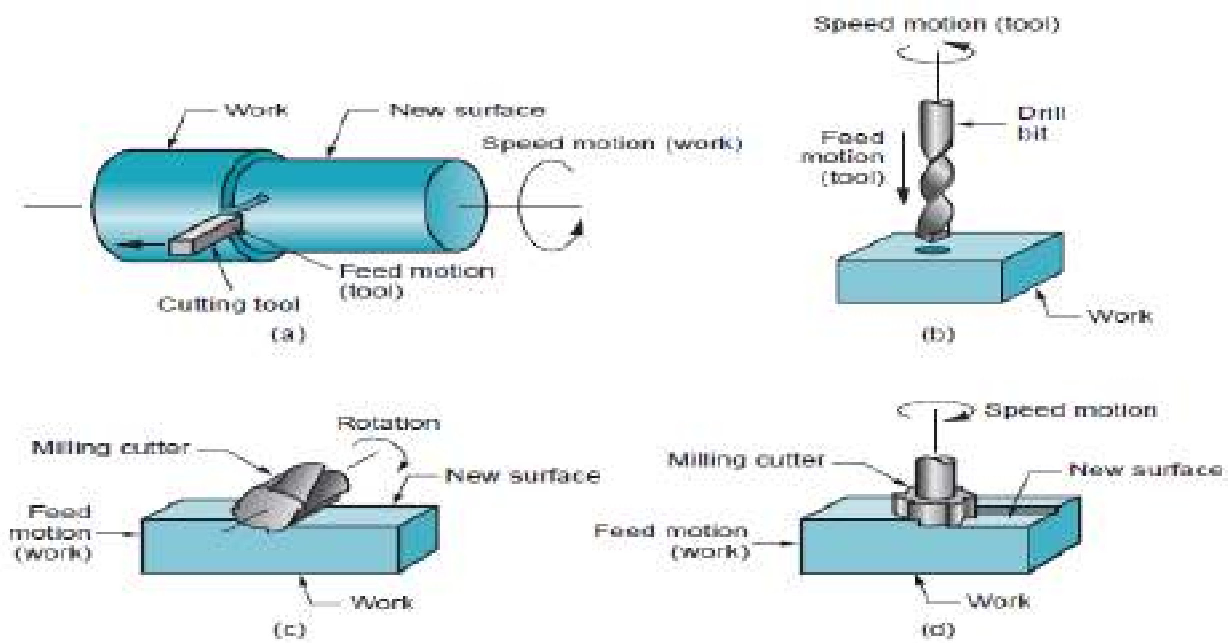
Most forging processes begin with open die forging. Open die forging is hot mechanical forming between flat or shaped dies in which the metal flow is not completely restricted. The stock is laid on a flat anvil while the flat face of the forging hammer is struck against the stock. The equipment may range from the anvil and hammer to giant hydraulic presses

Open-die hot forging is an important industrial process. Shapes generated by open-die operations are simple; examples include shafts, disks, and rings. In some applications, the work must often be manipulated (for

Metal Machining

Machining is not just one process; it is a group of processes. The common feature is the use of a cutting tool to form a chip that is removed from the workpart. To perform the operation, relative motion is required between the tool and work. This relative motion is achieved in most machining operations by means of a primary motion, called the cutting speed, and a secondary motion, called the feed. The shape of the tool and its penetration into the work surface, combined with these motions, produces the desired geometry of the resulting work surface.

Types of Machining Operations There are many kinds of machining operations, each of which is capable of generating a certain part geometry and surface texture, but for now it is appropriate to identify and define the three most common types: turning, drilling, and milling, illustrated in Figure



Why Machining is Important

- Variety of work materials can be machined
  - *Most frequently applied to metals*
- Variety of part shapes and special geometry features possible, such as:
  - *Screw threads*
  - *Accurate round holes*
  - *Very straight edges and surfaces*
- Good dimensional accuracy and surface finish

Drilling and Related Operations

Drilling, Figure 1, is a machining operation used to create a round hole in a work part. This contrasts with boring, which can only be used to enlarge an existing hole. Most drilling operations are performed using a rotating cylindrical tool that has two cutting edges on its working end. The tool is called a *drill* or *drill bit*, the most common form of which is the twist drill.

The rotating drill feeds into the stationary work part to form a hole whose diameter is equal to the drill diameter. Drilling is customarily performed on a *drill press*, although other machine tools also perform this operation.

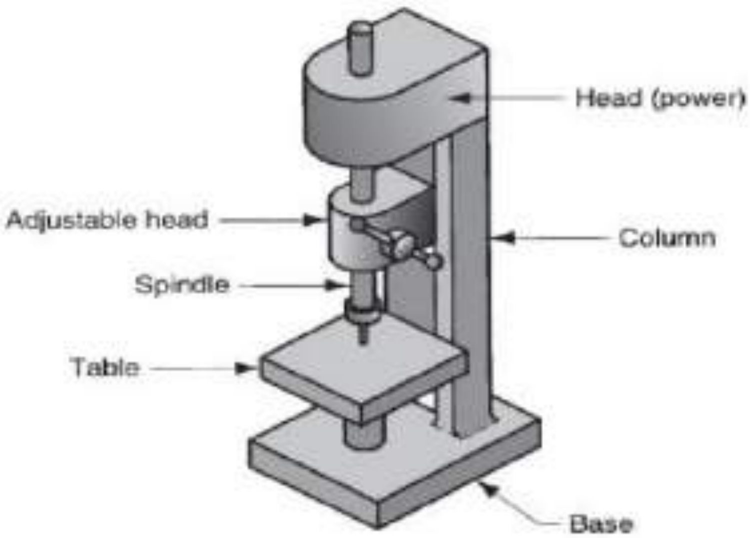


Figure 1: Drilling machine

Drills: Various cutting tools are available for hole making, but the *twist drill* is by far the most common. It comes in diameters ranging from about 0.15 mm to as large as 75 mm. Twist drills are widely used in industry to produce holes rapidly and economically. The standard twist drill geometry is illustrated in Figure 2. The body of the drill has two spiral *flutes* (the spiral gives the twist drill its name). The angle of the spiral flutes is called the *helix angle*, a typical value of which is around 30°. While drilling, the flutes act as passageways for extraction of chips from the hole. Although it is desirable for the flute openings to be large to provide maximum clearance for the chips, the body of the drill must be supported over its length. This support is provided by the *web*, which is the thickness of the drill between the flutes.

The point of the twist drill has a conical shape. A typical value for the *point angle* is 118°. The point can be designed in various ways, but the most common design is a *chisel edge*, as in Figure 2. Connected to the chisel edge are two cutting edges (sometimes called lips) that lead into the flutes. The portion of each flute adjacent to the cutting edge acts as the rake face of the tool.

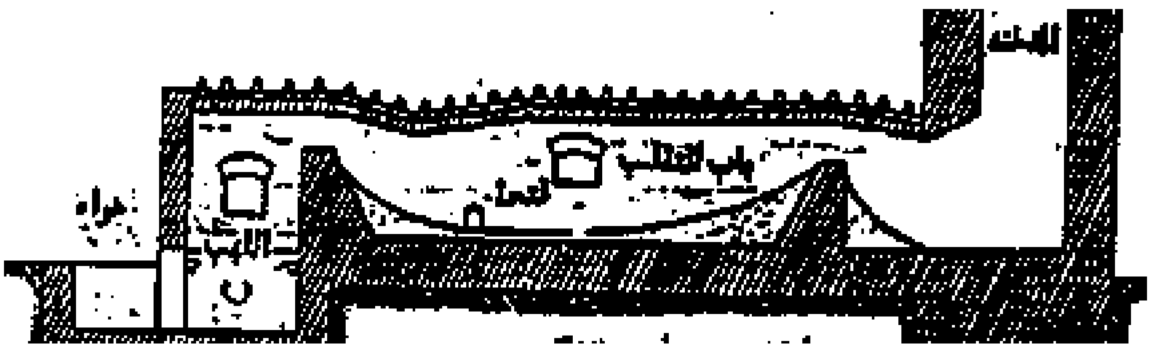
انتاج المعادن غير الحديدية

ملاحظة:
من المعادن غير الحديدية المستعملة على نطاق واسع في الصناعة ،النحاس والألمنيوم والقصدير والزنك والرصاص والنيكل و المغنسيوم ،ويفسر استعمال المعادن غير الحديدية وسبائكها بأن لبعضها خواص قيمة كجودة التوصيل الكهربائي والحراري ومقاومة الصدأ وصغر معامل الاحتكاك .

س/ وضح باختصار اهم الافران المستخدمة لاستخلاص المعادن غير الحديدية ؟

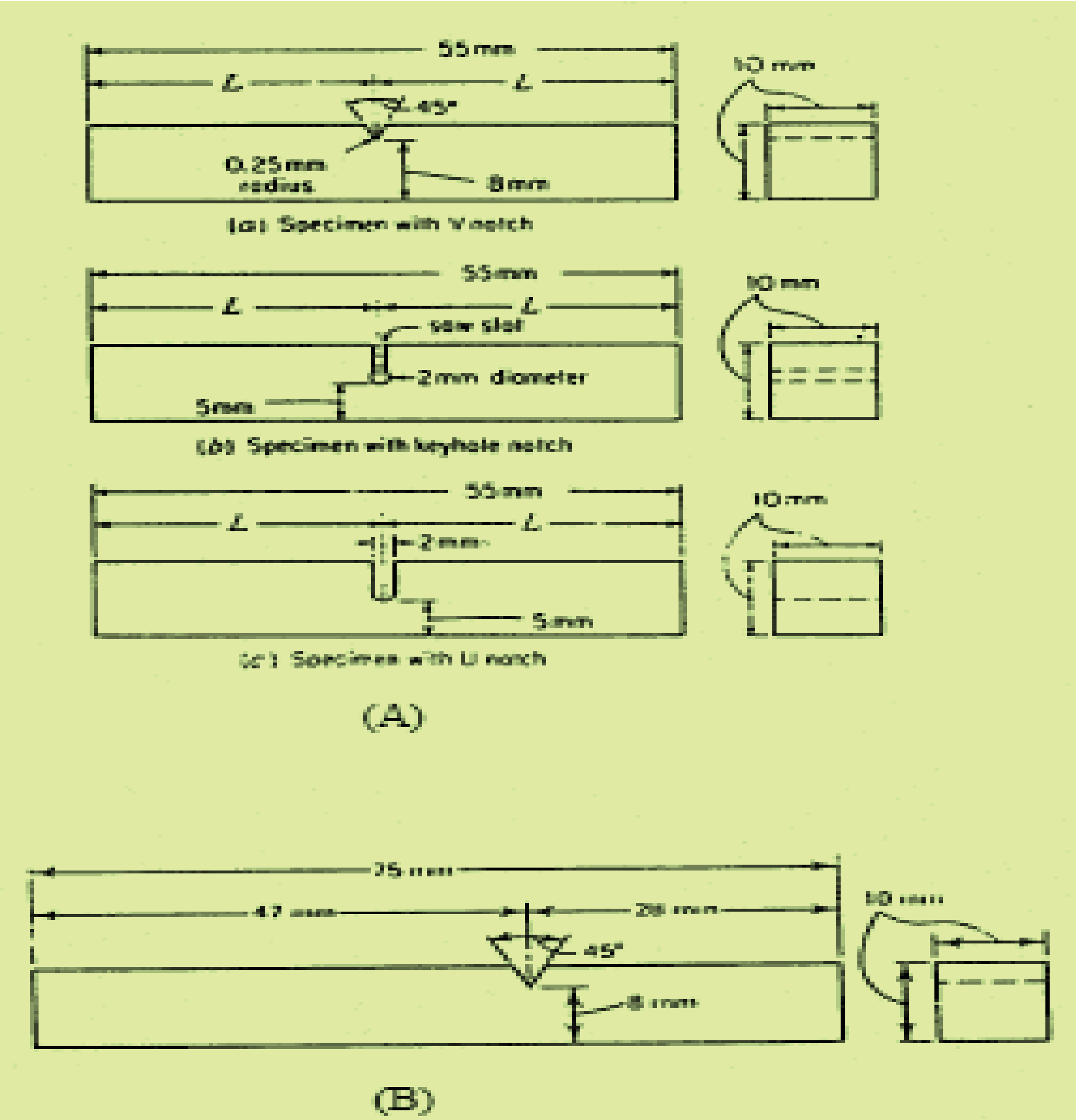
ج/

الفرن العاكس Reverbartory Furnace هو ابسط أنواع الأفران المستعملة في استخلاص المعادن غير الحديدية ،ويتكون هذا الفرن من موقد طويل وضيق كما مبين في الشكل ادناه، ويتم الشحن خلال سطح الفرن وذلك برفع بعض أجزاء من هذا السطح تدعى بالسدادات والخبث المتكون من إضافة المواد المساعدة يشكل طبقة تطفو على سطح المعدن المصهور وتقلل احتمال التأكسد الشديد للمعدن ، أما الوقود المستعمل في هذه الأفران فهو الوقود الغازي أو السائل. وسعة هذه الأفران فهي من (5) إلى (50) طن لكل صهره .



(الفرن العاكس)

تختلف اشكال العينات القياسية لكل من **اختبار أيزود** و**شاربي** من حيث شكل الحز(Recess) ففي **اختبار أيزود للصدم** يكون شكل الحز ثابت لكل العينات وهو مجرى بزاوية 45^o وعمق (2mm) أما في **اختبار شاربي** فيكون الحز بإشكال مختلفة وفي وسط العينة. **لاحظ الشكل ادناه**



A.اشكال عينات اختبار شاربي B.شكل عينة اختبار أيزود)

2.كيفية تثبيت عينات الاختبار بطريقة شاربي و أيزود

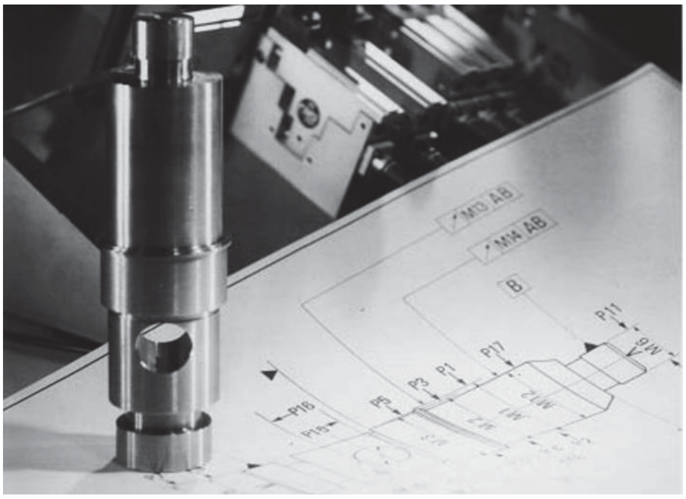
في **اختبار شاربي** تثبت العينة أفقيا بحيث تكون الصدمة تؤثر في منتصفها على الوجه المقابل للحز اما في حالة **اختبار أيزود** فتثبت العينة رأسيا في ماكينة الاختبار بحيث يكون قاع الحز في مستوي السطح العلوي لفكوك التثبيت وتكون الصدمة على نفس السطح العلوي المحتوي للحز. **لاحظ شكل تثبيت العينات في كلا الاختبارين.**

1. القياس Measuring

س/ما المقصود بالقياس ؟

ج/

القياس : هو مقارنة بين أبعاد المنتجات وبين مقاييس مجهزة بتداريج مكونة من عدد من وحدات القياس ،ويجب أن تتم المقارنة عدة مرات أثناء العمل للحصول على نتائج دقيقة بوساطة محددات القياس والفراجيل وأجهزة القياس الأخرى، حيث يمكن مراجعة المنتجات مراجعة دقيقة حتى تضمن أنها مطابقة للأبعاد المطلوبة. **لاحظ الشكل ادناه**



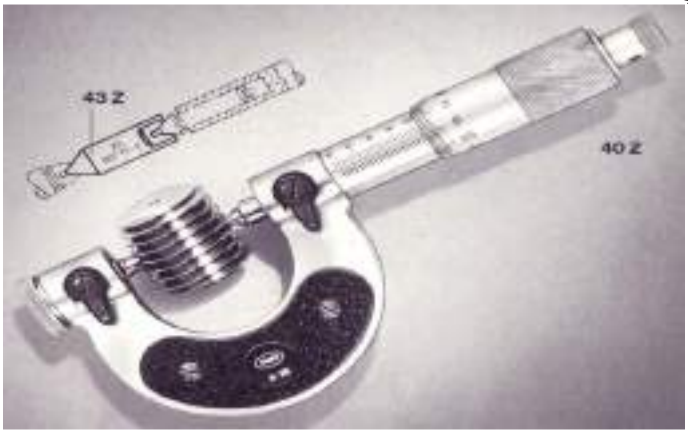
(مقارنة أبعاد القياس)

ملاحظة /

عند التشغيل الميكانيكي (عمليات قطع المعادن مثل الخراطة والتفريز وغيرها) يقاس طول وقطر وسمك المشغولات وزواياها وكذلك أبعاد القلاووظ (اللولب) وغير ذلك بوساطة أجهزة قياس يتوقف نوع هذه الأجهزة على نوع القياس المطلوب ،فمثلا لقياس الأطوال تستعمل مساطر القياس وقدمات القياس والميكرومترات ولقياس الزوايا تستعمل أداة تسمى زاوية الضبط والمنقلة القدمة ،وغيرها من عمليات القياس وأجهزتها المختلفة .

ملاحظة /

تكون الدقة هي العامل المهم في إختيار نوع أجهزة القياس إضافة إلى سهولة استعمالها وعدم تأثرها بالحرارة وكثرة الاستخدام لكي تعطي الدقة المطلوبة **لاحظ عملية قياس أبعاد القلاووظ**.



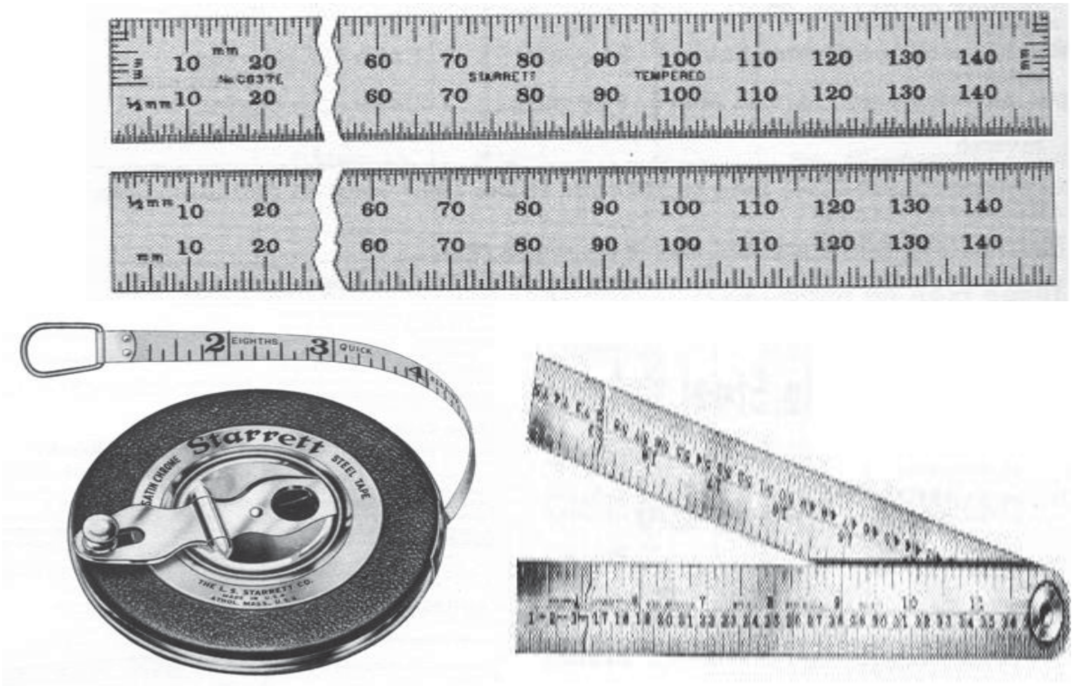
(عملية قياس أبعاد القلاووظ)

https://www.youtube.com/watch?v=e6xOIw5PqaY

Measuring Instruments أدوات القياس

1. المساطر وشرائط القياس The Measuring Rules and Tapes

تستعمل المساطر للقياس المباشر للمسافات القصيرة ،اما شرائط القياس (Measuring Tapes) فتستعمل لقياس المسافات الكبيرة. **لاحظ في الشكل ادناه بعض انواع المساطر والشرائط** .



(مساطر وشرائط القياس)

Steel Rule مسطرة الصلب

س/عرف مسطرة الصلب (Steel Rule) ؟

ج/

هي اقدم أداة من ادوات القياس واكثرها شيوعا في الاستعمال في عمليات القياس في الورش ،وهي توجد بأنواع واشكال عديدة وبفئات مختلفة من حيث الدقة ،وتدرج اما حسب النظام المتري (Metric System) او حسب النظام الانكليزي (British Standard) ,وتتوفر بأطوال مترية (150 ،300 ،600 و1000mm) ودقتها اما (1mm)أو (0.5mm). **لاحظ شكل مسطرة الصلب ادناه**.

(مسطرة الصلب)

تصنيف مساطر القياس

س /صنف مساطر القياس المختلفة ؟

ج/

تصنف مساطر القياس استنادا الى شكلها وتطبيقاتها الى :

1.مسطرة بحافة جانبية مدرجة: وتستعمل في قياس الاماكن الضيقة وعمليات القياس المختلفة.

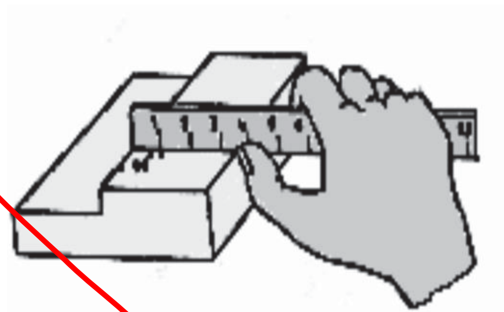
2.مسطرة صلب رقيقة : تستعمل في قياس الاطوال في الاماكن الضيقة كما تستخدم في جهاز قياس الاعماق .

3.مسطرة صلب مرنة : وهي مصنوعة من صلب النوابض بحيث يمكن حنيها على الشغلة وتستعمل في قياس الاطوال على الاسطح الدائرية .

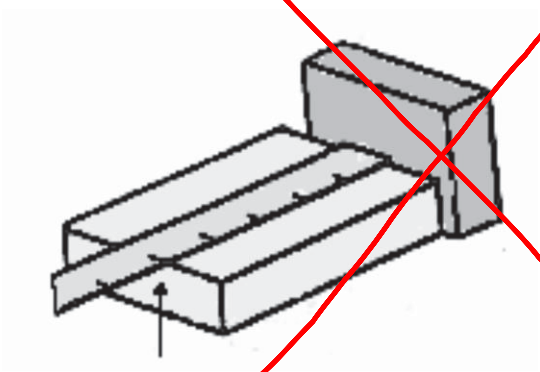
4.مسطرة صلب بحافة ارتكاز : تستعمل هذه المساطر في قياس ابعاد الشغلات المخفية التي لا يظهر طرف القياس او حافته بحيث لا يمكن مطابقة خط تدرج المسطرة الاعتيادية وفي هذه المساطر يكون التدرج ابتداء من حافة الارتكاز .

5.مسطرة صلب بماسك : وتستعمل في قياس الاطوال في المناطق الضيقة .

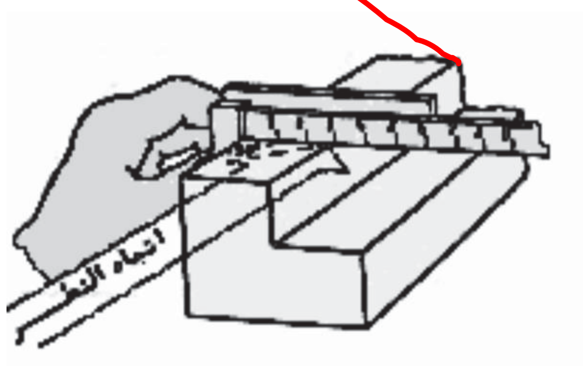
6.مسطرة صلب بحافة مشطوفة : تستعمل هذه المسطرة بصفة خاصة في قياس اطوال تنتهي بمنحنيات اتصال (Fillets) تمنع من استخدام مسطرة عادية .



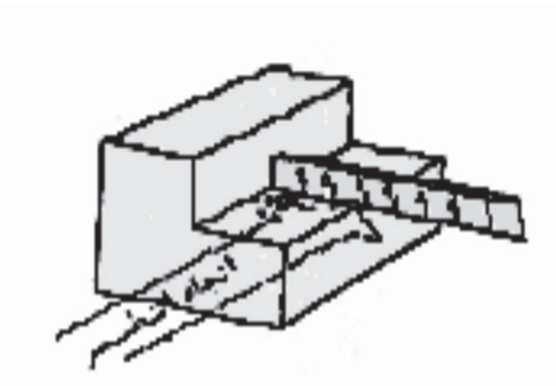
1.مسطرة بحافة جانبية



2.مسطرة صلب مرنة



2.مسطرة صلب بحافة ارتكاز



3.مسطرة صلب مشطوفه

(بعض اشكال وتطبيقات مساطر القياس)

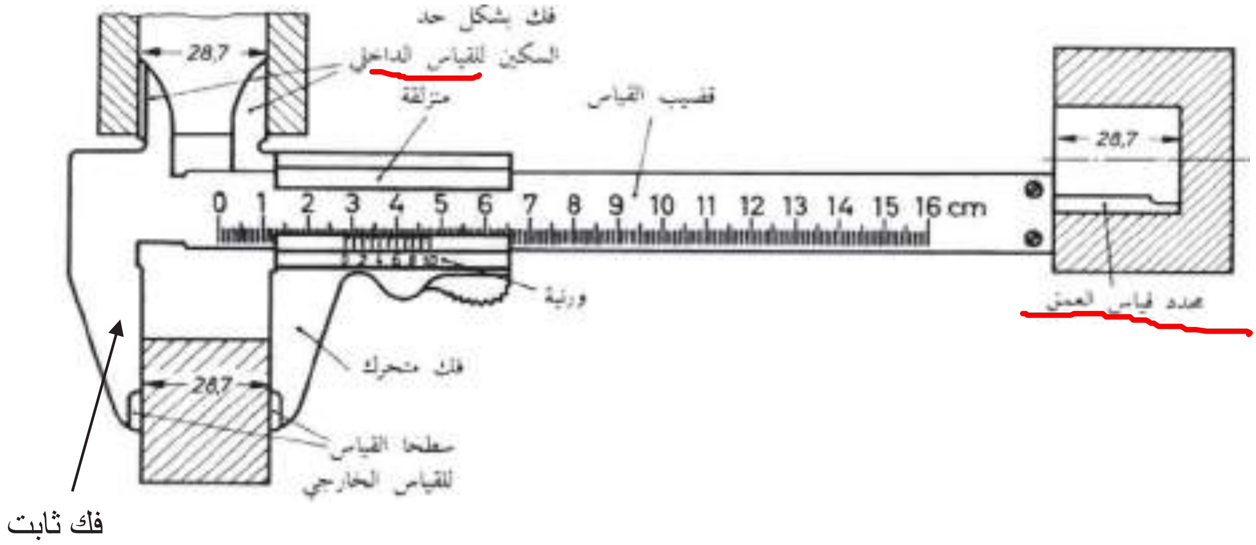
2.القدمة ذات الورنية Vernier Caliper

س/عرف القدمة ذات الورنية ؟

ج/

القدمة ذات الورنية: هي أداة دقيقة لقياس الأطوال يمكنها قياس أبعاد تصل إلى 0.02mm وتتكون من مسطرة قياس (قضيب قياس) مثبت عليها فكان ثابتان، وفكان متحركان يكونان كتلة واحدة مع الإطار ويتحركان معه على المقياس الأساسي (مقياس مسطرة القياس) ويثبت الإطار بواسطة مسمار ربط ،وللإطار عارضة مرسوم عليها تدريجات الورنية ويثبت مع الورنية ذراع قياس العمق (محدد قياس العمق) .

يبين الشكل ادناه الأجزاء الأساسية للقدمة ذات الورنية



(الأجزاء الأساسية للقدمة ذات الورنية)

دقة القدمة Accuracy

س/ما المقصود بدقة القدمة ؟

ج/

دقة القدمة : هي اصغر قياس مضغوط يمكن لهذه الأداة أن تقيسه وهي تختلف باختلاف عدد الأقسام على مقياس الورنية ،وتبعا لتقسيمات الورنية يمكن قياس الأجزاء باستخدام القدمة بدقة تساوي (0.1 ،0.05 و 0.02mm).

س/كيف يمكن حساب دقة القدمة ؟

ج/

يمكن حساب دقة القدمة (x) حسب العلاقة :

$$X = A - B$$

حيث :

A= طول التدريجة بالمقياس الاساسي بـ (mm)

B= طول التدريجة بمقياس الورنية بـ (mm) وهو يساوي طول مقياس الورنية (L) مقسوما على عدد تدريجات المقياس (N) .

$$B = \frac{L}{N}$$

ملاحظة مهمة :

يمكن الحصول على دقة القدمة مباشرتا من التعريف الاتي: **دقة القدمة = اقل قيمة يمكن قراءتها على التدريج الرئيسي \ عدد أقسام الورنية** ($X= \frac{A}{N}$)

مثال :
قدمة قياس ،طول مقياس الورنية فيها (9mm) وعدد تدريجات هذا المقياس (10) تدريجة وطول تدريجة المقياس الاساسي (1) ملم ، احسب دقة هذه القدمة ؟
الجواب :

A=1 mm
B = 9/10 = 0.9 mm
X =1- 0.9 = 0.1 mm مقدار دقة القدمة

مدى قياس القدمة Measuring Range

س / ما المقصود بـ (مدى القياس) ؟
ج/
يعني أقصى طول يمكن للقدمة أن تقيسه ،وهذا يعتمد على طول ساق القدمة وطول الورنية فيها ،حيث لا يمكن الحصول على قراءة باستخدام القدمة مساوية للطول الكلي لساق القدمة نفسها بسبب تحديد حركة الورنية ،لذلك فأن مدى القياس بالقدمة يمكن تحديده بالعلاقة التالية .

مدى القياس = طول ساق القدمة ـ طول مقياس الورنية

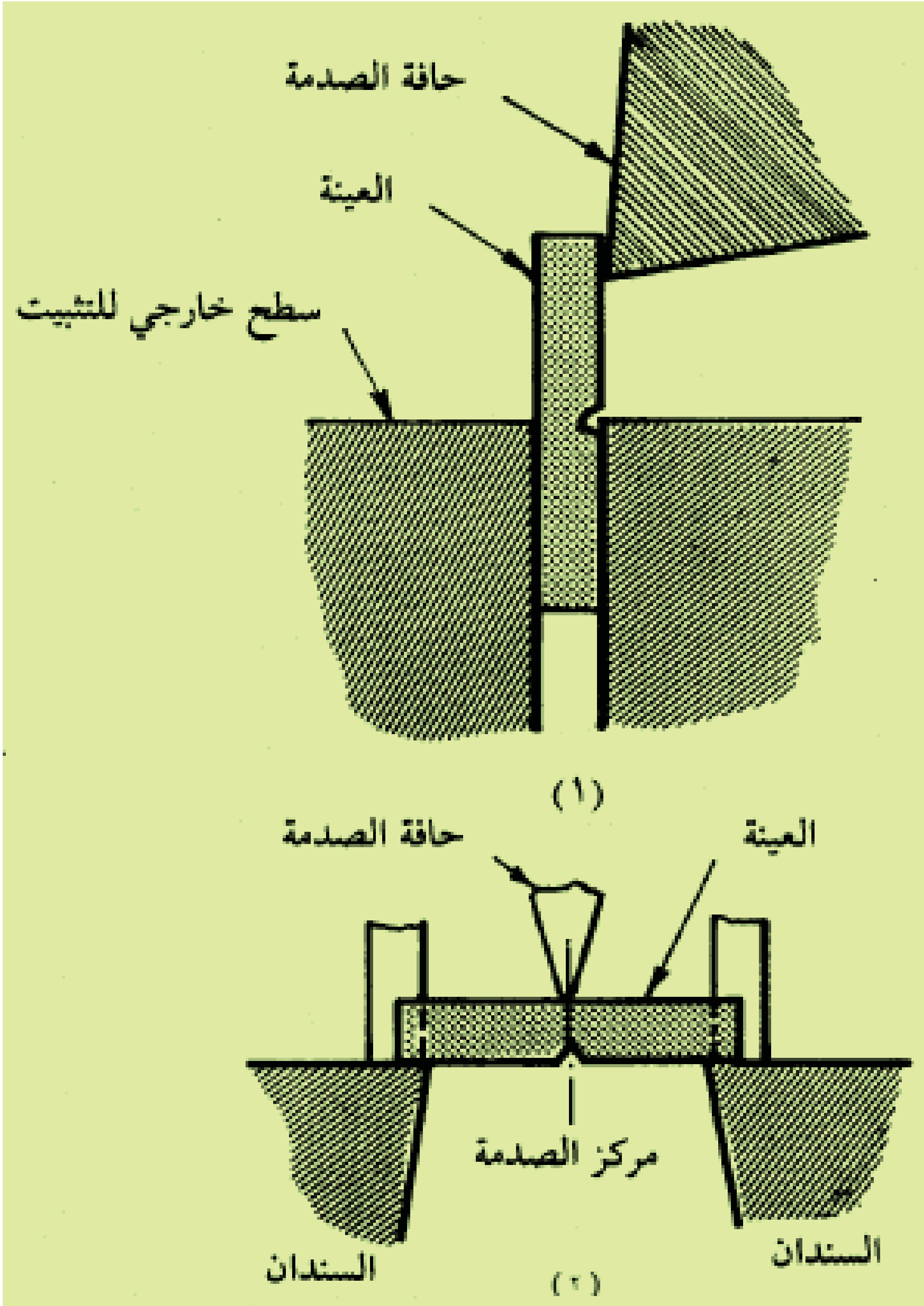
مثال :
قدمة قياس ،طول الساق المدرج فيها (150) ملم ،وطول مقياس الورنية (9) ملم مقسم إلى (10) اقسام ، ما مقدار دقتها ؟ ومدى القياس فيها ؟
ج/

X=A- B
X= 1- 9/10
X=0.1 mm

مدى القياس = طول الساق – طول مقياس الورنية
مدى القياس = 150 - 9
= 141 ملم

اسئلة للمناقشة

س1/ما المقصود بالقياس؟عدد اهم ادواته .
س2/احسب الدقة ومدى القياس لقدمة قياس مترية ،مقياس الورنية فيها مقسم الى 25 تدريجه ،يقابله 24 تدريجه على المقياس الرئيسي (كل 1 تدريجه من المقياس الرئيسي = 0.5mm) وطول الساق المدرجة فيها 30cm ؟
س3/ما فائدة مدرج القدمة ؟وضح ذلك بالرسم مع ذكر مثال على ذلك ؟
س4/صنف مساطر القياس على اساس الاستخدام ؟موضحا بالرسم كيفية استخدام كل نوع ؟
س5/ما العوامل الاساسية التي تحددك في اختيار نوع اجهزة القياس ؟
س6/ارسم قدمة القياس وبين اهم اجزائها ؟
س7/ما الفائدة العملية من معرفة :1.دقة القدمة 2.مدى القياس فيها ؟
س8/مسطرة صلب بحافة ارتكاز اثناء عملية اخذ القياس موضحا اجزائها ؟



(طرق تثبيت العينات في اختبار الصدم 1.طريقة أيزود 2.طرية شاربي)

3.كيفية اجراء الاختبار

1.توضع العينة بين فكي الجهاز الموضح في الشكل ادناه .

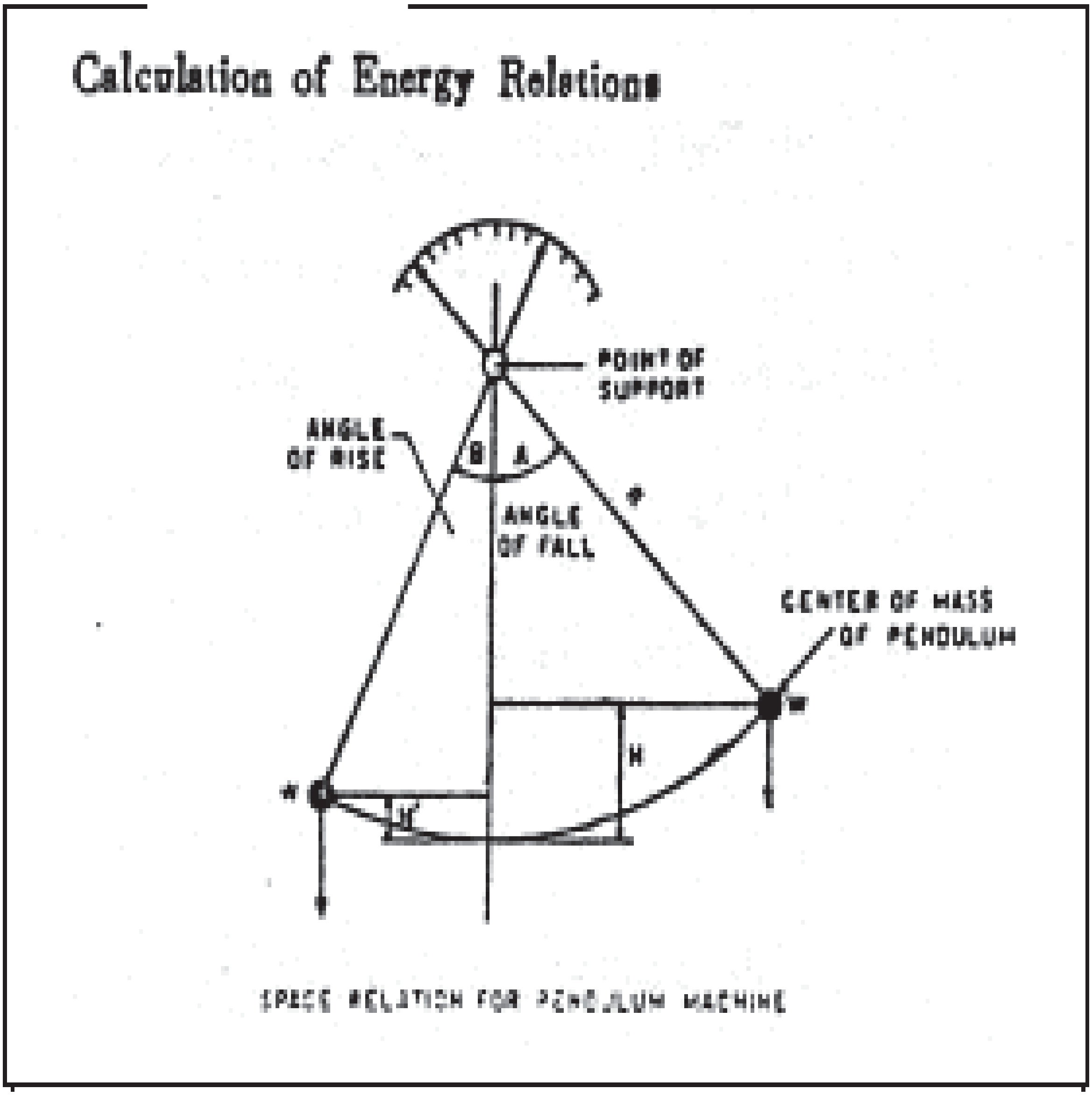
2.يرفع الحمل الى ارتفاع معين (H) ويترك ليسقط على العينة ليرتفع بعد ذلك الى ارتفاع اخر (h) .

3.يكون الفرق في طاقة الوضع بين الارتفاعين معيارا لمقاومة المعدن للصدمات .

4.بعد تحديد وزن كتلة البندول (W) فأن مقاومة المعدن للصدمات (α_k) تحسب وفق العلاقة :

$$\alpha_k = \frac{W\,(H - h)}{A} \quad (Kg/Cm^2)$$

حيث: A المساحة عند الحز بالسنتمتر المربع .



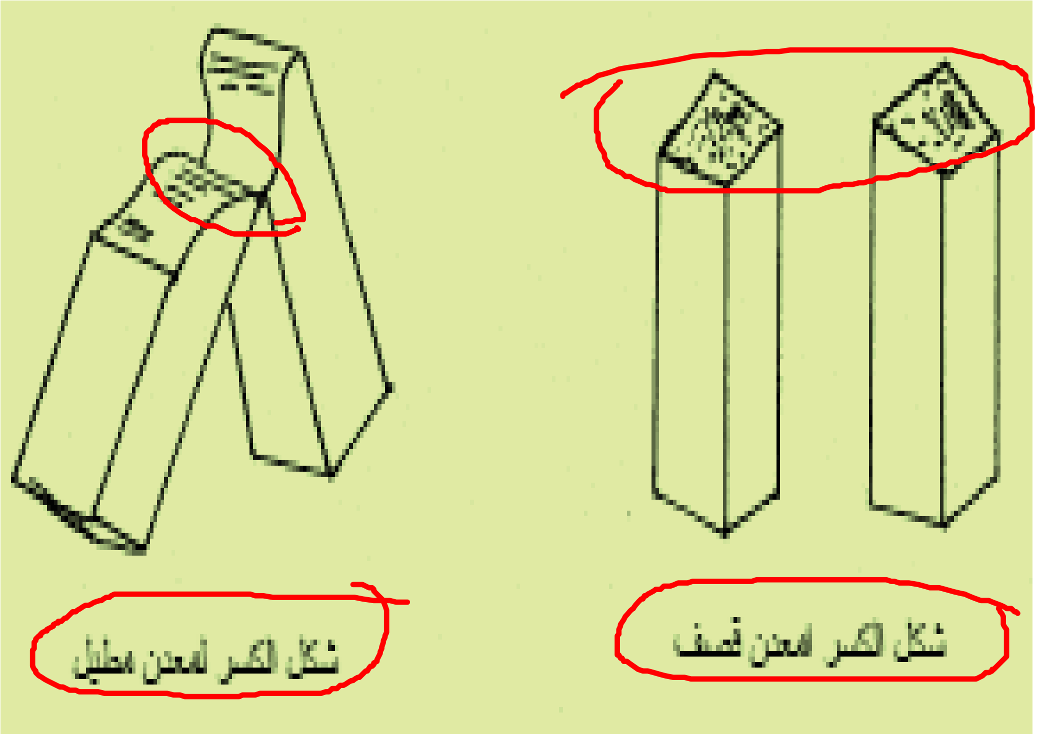
(مخطط توضيحي لماكنة الصدم)

4.نتائج الاختبار

1.عند الحصول على مقاومة المعدن للصدمات يتم مقارنتها بنتائج قياسية فهي تختلف باختلاف نوع المعدن فاذا كانت قيمة هذه المقاومة منخفضة جدا (0.1 – 0.2 كجم\سم^2)فذلك يعني ان المادة هشة كالحديد الزهر اما اذا كانت تتراوح قيمتها بين 2 و12 كجم\سم^2 فذلك يعني ان الحديد المفحوص من الحديد الصلب.

2.من الملاحظ ان شكل الكسر للعينة في كل من اختباري شاربي و أيزود يعكس خاصية مطيلية المعدن أو قصافته فالمعدن المطيلي تثنى عينته مع الكسر أما المعدن القصيف فتكسر عينته عند الحز.

لاحظ الشكل ادناه



(اشكال الكسر في اختبار الصدم للمعادن المطيلية والقصفة)

ملاحظة :

يمكن حساب الشغل المبذول لكسر العينة من جداول تعطى فيها قيمة هذا الشغل حسب زاوية ارتفاع البندول بعد الصدمة وتحدد زاوية ارتفاع البندول بواسطة مؤشر ينزلق على تدريج الجهاز .

أسئلة للمراجعة

س1/ما المقصود باختبار مقاومة الصدمات ؟

س2/عرف المتانة واشرح طريقة لقياسها ؟

س3/ما المقصود بالتقصف ؟كيف تقاس خاصية التقصف ؟

3.اختبار الصلادة Hardness Test

س/ما المقصود بالصلادة (Hardness)؟

ج/

الصلادة تعبير عن مقاومة المعدن للخدش والاختراق بواسطة المواد الاخرى وهي خاصية هامة جدا وخصوصا في الأجزاء المعرضة للاحتكاك الانزلاقي كأعمدة الدوران التي تدور داخل كراسي (ركائز) انزلاقية واسطح فرش وعربات الات الورش التي تنزلق أثناء حركتها .

س/علل :لقي اختبار الصلادة انتشارا واسعا في المجال الصناعي ؟

ج/

وذلك لأنه يتم بسهولة وسرعة دون أن ينتج عنه تحطيم للمعدن المراد اختباره .

طرائق اختبار الصلادة

1.اختبار صلادة برينل Brinell Hardness Number

تستعمل هذه الطريقة لقياس صلادة الاجزاء غير المقساة (غير المصلدة) كالقطع المدرفلة والمطروقات والمسبوكات والمكبوسات المعدنية وغير المعدنية المنخفضة او المتوسطة الصلادة .

س/كيف يتم اجراء اختبار صلادة برينيل ؟

ج/

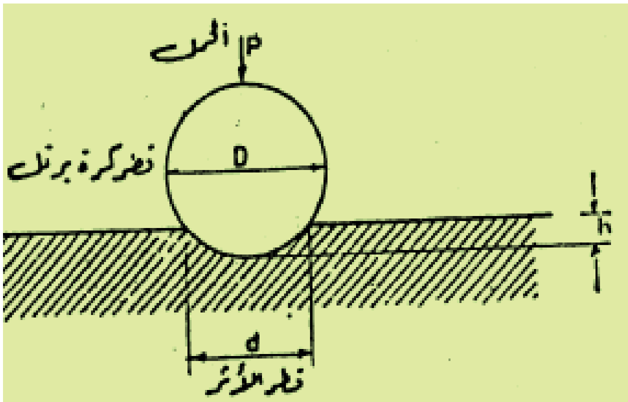
بعد تنظف سطح المعدن المراد اختباره على حجر تجليخ او بالصنفرة ، يضغط على سطح المعدن بكرة من الصلب المقسى ذات قطر (D) ملم وبحمل قدره (P) كغم ثم يقاس الاثر (d) ملم الناتج من هذا الضغط على سطح قطعة الاختبار وذلك بعد ازالة الحمل المؤثر ويعبر عن صلادة المعدن المختبر برقم برينل للصلادة (B.H.N) والذي يحسب كمايلي :

$$B.H.N=\frac{2P}{\pi D(D-\sqrt{D^2-d^2})}$$

حيث ان :

P – مقدار الحمل المسلط kg، D – قطر الكرة المستخدمة mm، d - قطر أثر الكرة mm،

لاحظ الشكل ادناه والذي يبين ابعاد كرة برينيل وقطر الاثر الذي تحدثه اثناء الفحص .



(ابعاد كرة برينيل وقطر الاثر اثناء الفحص)

2.اختبار صلادة المعادن بطريقة روكويل Rockwell

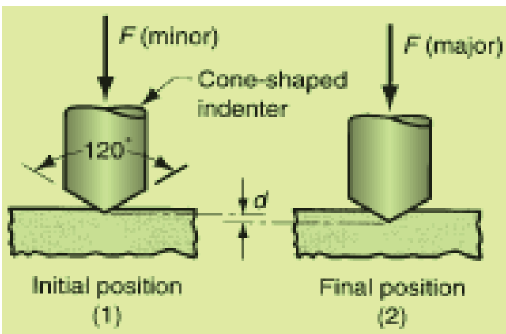
يجرى اختبار روكويل باستخدام ماكينة خاصة تؤثر بحمل 60 أو 100 أو 150 كغم وهو حمل صغير بالنسبة للحمل المستعمل في برينل لاحظ الشكل والذي يبين جهاز اختبار روكويل .

جهاز اختبار روكويل

س/كيف يتم اجراء اختبار فحص الصلادة بطريقة روكويل ؟
ج/

لا اختبار صلادة المعادن بطريقة روكويل ،تضغط على سطح الجزء المراد اختباره كرية من الصلب قطرها 1.59 ملم أو مخروط من الماس زاوية قمته 120° وتختبر المواد اللينة بالكرية المصنوعة من الصلب اما المواد الصلدة فتختبر بالمخروط الماسي .

يجرى الاختبار بتحميل قطعة الاختبار بحمل ابتدائي قيمته 10 كغم (Minor load) وبعد ذلك يعاد مؤشر القرص المدرج للجهاز أمام التدريج ،ثم يزاد الحمل بإضافة الحمل الكبير (Major load) حتى يكون الحمل الكلي النهائي 60 أو 100 أو 150 كغم حسب نوع اختبار روكويل المستخدم (**الحمل النهائي = الحمل الابتدائي +الحمل الكبير المضاف**) .



(اختبار ركويل)

ملاحظة :

1.أثناء التحميل بالحمل الكبير المضاف يسير الجسم المحدث للأثر داخل سطح قطعة الاختبار و في نفس الوقت يتحرك مؤشر القرص المدرج للجهاز لأنه متصل بالجسم المحدث للأثر بحيث انه كلما زاد عمق الاثر كلما زادت حركة دوران المؤشر على قرص الجهاز .

2.يزال الحمل الكبير المضاف فيقل عمق الاثر قليلا و يرتد بالتبعية قليلا المؤشر على القرص ويثبت عند تدريج معين يكون رقمه هو **رقم روكل للصلادة** (مع ملاحظة ان الحمل الابتدائي 10كغم لازال مؤثرا على قطعة الاختبار اي ان رقم الصلادة يتعلق بالأثر الناتج من الحمل الكبير فقط)

3.بنى روكويل طريقته على اساس أن رقم المبين على تدريج الجهاز يتناسب تناسبا عكسيا مع عمق الاثر الناتج من الحمل الكبير اي انه كلما زاد عمق الاثر كلما صغر رقم روكويل للصلادة اي كلما قلت صلادة المعدن المختبر .

4.من مميزات طريقة روكويل الدقة الكبيرة و الانتاجية العالية و صغر الاثر (الختم) الذي يتركه الاختبار على المصنوعة وبساطة الاختبار .

5.هناك مقاييس مختلفة لتحديد الصلادة بطريقة روكويل منها :

أ .**مقياس صلادة روكويل B او(HRB)** وتستخدم فيه كرية الصلب وحمل كلي 100كغم وتحدد بها صلادة الصلب الكاربوني الطري والمتوسط والالواح والقضبان المعدنية الطرية .

ب .مقياس صلادة روكويل C أو (HRC) و يستخدم فيه المخروط الماسي و حمل 150كغم و تحدد بها صلادة الصلب المصلد و السبائك الحديدية و السبائك المعدنية ذات صلادة اكثر من روكويل 100.

جـ .مقياس صلادة روكويل A أو (HRA) و يستخدم فيه مخروط ماسي و بحمل 60كغم و تحدد صلادة شرائح الصلب المصلد الرقيقة و المعادن و السبائك شديدة الصلادة و في اختبار الصلادة اذا اريد ان يكون الاثر الحادث صغيرا.

لاحظ الجدول ادناه الذي يبين مقاييس ركويل

TABLE 3.5 Common Rockwell hardness scales.

Rockwell Scale	Hardness Symbol	Indenter	Load (kg)	Typical Materials Tested
A	HRA	Cone	60	Carbides, ceramics
B	HRB	1.6 mm ball	100	Nonferrous metals
C	HRC	Cone	150	Ferrous metals, tool steels

3.اختبار صلادة المعادن بطريقة فيكرز Vickers

تسمح هذه الطريقة بقياس صلادة الطبقات السطحية الرقيقة الناتجة عند الكربنة او النتردة او المعاملة (الكربونتروجينية) كما يمكن بواسطتها قياس صلادة المواد الشديدة الصلادة والمصنوعات ذات المقطع الصغير ،وتعين الصلادة بضغط هرم رباعي ماسي زاوية قمته 136^0 في المادة المختبرة ويجري الضغط تحت تأثير حمل قدره - 5 ،10، 20، 30، 50، 100 أو 120 كغم ثم تقدر مساحة الاثر الناتج بقياس قطره بواسطة ميكروسكوب مثبت على الجهاز أو ان هذا الاثر يظهر مكبرا على شاشة الجهاز حيث يمكن قياس قطر الاثر بدقة او ان الجهاز يعطي مباشرة عن طريق مقياس خاص قيمة رقم فيكرز للصلادة .

ملاحظة :

1. يحسب رقم فيكرز للصلادة من المعادلة :

$$\text{Vickers hardness number} = \frac{2.p.\sin(\emptyset/2)}{D^2} = 1.854\,\frac{P}{D^2}$$

2.ان رقم فيكرز ثابت للمعدن الواحد مهما اختلفت الاحمال المؤثرة .

3.يمكن باختبار فيكرز الحصول على قيمه دقيقة لرقم الصلادة وتعبير تام عن صلادة المعدن المختبر وذلك مع استخدام جهاز صغير الحجم واحمال مؤثرة صغيرة كما يمكن لهذا الاختبار باستخدام الهرم الماسي الدقيق الحجم تحديد صلادة المعادن شديدة الصلادة وقليلة الصلادة والمعادن الرقيقة السمك التي لا يصلح لها اختبار برينل وذلك حتى سمك 0.1 ملم .

4.يستعمل هذا الاختبار في الاعمال التي تتطلب نتائج دقيقة للمعادن مهما اختلف النوع او تنوعت الابعاد او اختلفت الصلادة ،ويعتبر اختبارا هاما في اعمال المقارنة والابحاث .

ملاحظة :

توجد أساليب مهمة لا اختبار الصلادة بأجهزة بسيطة منها جهاز قياس الصلادة بالكرة المرتدة (الصلادة المرنة)،حيث تقاس الصلادة في هذه الطريقة بأسقاط قرص صغير ،يحتوي في مركزه على كرة فولاذية مصلده او نقطة صغيرة من الماس على سطح القطعة المعدنية المراد قياس صلادتها واحتساب ارتفاع الارتداد عن سطح المعدن بعد الارتطام به حيث يتناسب هذا الارتفاع طرديا مع صلادة المعدن .ونظرا لصغر حجم الجهاز ،يكثر استعماله لقياس صلادة القطع المعدنية في مواقع العمل او الانتاج كما انه يستعمل ايضا لقياس صلادة المنتجات المنجزة لا انعدام او صغر الاثر الذي يتركه على هذه القطع بعد عملية القياس .

اسئلة للمراجعة

س1.كيف يجرى اختبار برينل

س2.كيف يمكن حساب متانة الشد بصورة تقريبية من الصلادة البرينيلية

س3.بم يضغط على العينة الاختبارية في اختبار فيكرز

س4.ما الحمل المستخدم في اختبار روكويل

س5.عرف الصلادة واشرح طريقة لقياس صلادة قطعة منجزة دون تخديش سطحها

3. خواص الميكانيكية اخرى

توجد مجموعة اخرى من الخواص الميكانيكية الهامة منها:

1.الزحف (Creep)

هي الظاهرة التي يستطيل عندها المعدن تحت تأثير قوة ثابتة .تؤخذ تأثيرات الزحف بجدية شديدة خاصتا عند تصميم توربينات الغاز والبخار التي تعمل عند درجات الحرارة العالية حيث يسهل الزحف

2.الكلال (Fatigue)

تسمى ظاهرة انكسار المعدن تحت تأثير الاجهادات المتكررة او المتغيرة الاتجاه (بالكسر الكلالي) للمعادن .ويمكن ان يحدث الكسر الكلالي عند اجهادات تقل كثيرا عن المقاومة القصوى وقد تقل حتى عن مقدار حد الانسياب وتسمى قدرة المعدن على مقاومة الانكسار في هذه الظروف (بمقاومة الكلال) والسبب في كلال المعادن هو الانزلاقات التي تحدث في الحبيبات البلورية الموجودة في اسوأ وضع بالنسبة للقوى المؤثرة وتساعد هذه الانزلاقات على تكوين شقوق بالغة الدقة ،تزداد تدريجيا تحت تأثير التحميل المتكرر او المتغير الاتجاه . تحدث ظاهرة الكلال كما بينت التجارب عند تخطي اجهاد الكلال لحد الكلال للمادة وحد الكلال **(Fatigue Limit)** هو اكبر اجهاد تتحمله المادة خلال عدد معين من دورات التحميل دون ان تنكسر وهناك عدد كبير من الماكنات الخاصة لاختبار مقاومة الكلال عند الانثناء والشد واللي ..الخ .

تعريف

اسئلة السنين السابقة

8.إنتاج النحاس Production of Copper

س /ماهي اهم خامات النحاس الموجودة بالقشرة الأرضية والتي يتم استخلاصه منها ؟

ج/

1.بيريت النحاس (Copper Pyrite) وهو أكثر خامات النحاس انتشارا فهو اوكسيده الأحمر وكبريتيدة المزدوج مع الحديد($Cu_2SFe_2S_3$)حيث يحتوي على نحاس بنسبة (32%).

2.الهالكوزايت (Cu_2S).

3.البورنيت أوالخام الأرقط ($Cu_2S.FeS.\ CuS$) .

4.الكوبريت ،خام اوكسيد النحاس (Cu_2O) ويعتبر من الخامات الفقيرة .

س/وضح ماهي طرائق انتاج النحاس ؟

ج/

هناك طريقتان لإنتاج النحاس :

1.الطريقة الجافة Dry Process .2 الطريقة الرطبة Wet Process

سبائك النحاس Copper Alloys

س/ماهي اهم سبائك النحاس المستخدمة في الصناعة وما هي مكوناتها؟

ج/

1.البرونزBronze

وهي سبيكة من النحاس والقصدير وتختلف نسبة تكوينه باختلاف الغرض من استخدامه فهناك **سبيكة المدافع (Gun Metal)**التي تحتوي على 10%قصدير و88%نحاس و2% زنك والتي تستخدم في المسبوكات الثقيلة. وهناك أيضا ***البرونز الفسفوري*** ويتكون من% 16قصدير و83.5% نحاس و0.5% فوسفور و يستخدم في صناعة التروس و أجزاء الماكينات المعرض للإجهادات . ويمتاز البرونز بقابليته العالية للتشغيل على الماكينات لذلك فهو شائع الاستخدام في كثير من أجزاء الماكينات .

2.النحاس الأصفر Brass

وهو سبيكة من النحاس و الزنك وتختلف نسبة النحاس إلى الزنك في السبيكة باختلاف التطبيق وتمتاز سبائك النحاس الأصفر بمظهرها اللامع ولونها الأصفر الجميل كما تمتاز بمقاومتها للتآكل.

اسئلة واجب بيتي

س 1 / اكتب معادلة ترسيب النحاس في خلية التحليل الكهربائي ؟

س2/عرف كل من المصطلحات التالية :

1.سبيكة المدافع 2.النحاس الاصفر 3.البرونز4.بيريت النحاس

س3/قارن بين الطريقة الجافة والطريقة الرطبة لإنتاج النحاس ؟

س4/قارن بين البرونز والنحاس الاصفر من حيث الغرض والمكونات .

9.إنتاج الألمنيوم Production of Aluminum

س/ماهي خامات الالمنيوم التي انتشر استخدامها في الصناعة ؟

ج/

أهم خامات الألمنيوم التي انتشر استخدامها انتشارا كبيرا في الصناعة هي اوكسيد الألمنيوم المائي ($Al_2O_3.3H_2O$) المعروف بـ (البوكسايت) ،وأهم أنواع البوكسايت المعروفة صناعيا هي البوكسايت الأبيض والبوكسايت المحمر.

س/عرف البوكسيت (Boxite) ؟

ج/

هو المادة الخام الرئيسية للحصول على الألمنيوم و البوكسيت عبارة عن صخر معدني مركب يحتوي على هيدروكسيد الألمنيوم طليقاً بنسبة 40% إلى 60% ويحتوي بالإضافة إلى ذلك عدداً من الشوائب كأكسيد الحديد والسيليكا وغيرها.

س/كيف يتم انتاج الالمنيوم من خاماته ،وضح ذلك بالمعدلات الكيميائية موزونة؟

ج/

يتم إنتاج الألمنيوم على مرحلتين :

1.الحصول على أوكسيد الألمنيوم (الالومينا)من البوكسيت، حيث يعامل الخام الذي يحتوي على كمية صغيرة من السيليكا بالمواد القلوية لتحويل هيدروكسيد الألمنيوم إلى الومينات الصوديوم :

$$2Al(OH)_3 + 2NaOH = Al_2O_3Na_2O + 4H_2O$$

وتذوب الالومينات الناتجة في الماء، أما اكاسيد الحديد والكالسيوم وغيرها فإنها تكون رواسب صلبة غير قابلة للذوبان تفصل على المرشحات الكابسة. ويجري المحلول المائي المرشح لألومينات الصوديوم إلى أحواض بها قلابات يتحلل فيها المحلول بواسطة التحليل الكهربائي فينفصل منه راسب صلب من هيدروكسيد الألمنيوم:

$$Al_2O_3Na_2O + 4H_2O = 2Al(OH)_3 + 2NaOH$$

ويرسل الراسب إلى الفرن حيث يتحول عند درجة حرارة 1300م إلى اوكسيد الألمنيوم غير المائي $A1_2O_3$.

2.التحليل الكهربائي للالومينا للحصول على الألمنيوم النقي ،ويتلخص الحصول على الألمنيوم من الالومينا في تحليل اكسيد الالمنيوم كهربائياً في أحواض الكريوليت (AlF_33NaF) المصهور الى مكوناته .ومن خواص الكريوليت القدرة على إذابة الالومينا، ثم تحلل بعد الإذابة كهربائياً فينفصل الألمنيوم النقي إلى قاع أحواض التحليل.

سبائك الألمنيوم

س /مما تتكون سبائك الالمنيوم؟

ج/

تتكون سبائك الألمنيوم من الألمنيوم كأساس لها وبعض العناصر الأخرى ، واهم المعادن التي تخلط مع الألمنيوم لتحسين خواصه هي السيلكون والنحاس والمغنسيوم والخارصين والنيكل والحديد ،وسبائك الألمنيوم أكثر متانة ومقاومة للتآكل والصدمات من الألمنيوم النقي ،وهي واسعة الاستعمال في الصناعات المختلفة .

س/صنف سبائك الالمنيوم ؟

ج/

1.سبائك الألمنيوم القابلة للتشكيل (بأساليب الطرق والصب و الدرفلة و البثق.. الخ)ومن هذه السبائك الدور لومين (Duralumin) ذو المتانة العالية ومقاومة التآكل الكيميائي والذي يستخدم في صناعة بعض أجزاء الطائرات وأجسامها.

2.سبائك الألمنيوم للمسبوكات (السباكة الرملية والسباكة في قوالب معدنية ..الخ)ومنها سبائك السيلومين (Silomin Alloys)أو سبائك الالمنيوم والسيلكون (Al-Si).

10.إنتاج الرصاص

س/ماهي اهم الخامات التي يستخلص الرصاص منها ؟

ج/

اهم خامات الرصاص هو اللياترج PbS وتتراوح نسبة الرصاص في الخام بالمتوسط من 6- 16%.

س/اشرح طريقة استخلاص الرصاص من خامته ؟استعن بالمعدلات الكيميائية موزونة ؟

ج/

يستخلص الرصاص بطريقة الصهر الاختزالي للخام المركز بعد تحميصه مبدئياً. ويجري التحميص المبدئي في أفران عاكسة لتحليل كبريتيد الرصاص PbS وتحويل الرصاص الى كبريتات $PbSO_4$ ويمكن بواسطة التحميص الثانوي التخلص تماماً من الكبريت والحصول على PbO. ويختزل الرصاص عند الصهر في أفران اسطوانية بواسطة كربون فحم الكوك حسب المعادلتين:

$$PbO + c = Pb + co$$

$$PbO + co = Pb + co_2$$

ويحتوي الرصاص الناتج بعد الاختزال على شوائب بنسبة تصل إلى (15%)ويحتوي الرصاص بعد تنقيته على نحو(99.95%) من عنصر الرصاص.

4.الانعكاس الضوئي Light Reflection

معظم المعادن تعكس الاشعة الضوئية ،لذا فان لونها الطبيعي ابيض او اقرب ما يمكن الى البياض ويشذ عن ذلك النحاس والذهب بينما كثير من المواد غير المعدنية لا تعكس الضوء.

5.نفاذ الاشعة السينية X-ray Penetration

المعادن صعبة الاختراق بواسطة الاشعة السينية بينما اغلب المواد غير المعدنية تسمح بنفاذ الاشعة السينية.

6.القابلية للمغنطة Magnetizability

اكثرية المعادن قابلة للمغنطة بعكس اغلب المواد غير المعدنية .

7.الميوعة fluidity

وهي قابلية المعدن على السيولة والانسياب عند درجات الحرارة العالية . وتمتاز اغلب المعادن بانها ذات درجة انسياب عالية عند درجات الحرارة العالية. ويمتاز الزئبق بانه مائع عند درجة حرارة الغرفة.

8.الانصهار المحلي fusability

وهي قابلية المعدن على الانصهار عند نقاط محددة اذا سلطت على هذه النقط حرارة عالية ويستفاد من هذه الخاصية في عمليات اللحام المختلفة.

الخواص الميكانيكية Mechanical Properties

تحدد الخواص الميكانيكية، قدرة المواد على مقاومة تغير شكلها ،وانهيارها عند وقوعها تحت تأثير القوى الخارجية ،وتتوقف هذه الخواص على نوع المادة وطريقة تشغيلها وبنيانها الداخلي وشكل المصنوعة وعلى عدد من العوامل الاخرى.

س/عدد اهم الخواص الميكانيكية للمعادن ؟

ج/

1.المطيلية Ductility

وترمز الى قدرة المعدن على تقبل التغير في شكله تحت تأثير قوى الشد(Tension) او الانحناء (Bending) او السحب (Drawing) بدون حدوث الكسر كما في عمليات سحب الاسلاك وسحب الانابيب .

2.الطروقية Malleability

وترمز الى قدرة المادة على قبول التغير في شكلها تحت تأثير الضغط (Compression). وقابلية الطرق هي الخاصية التي تساعد الجسم على التمدد بصفة ثابتة في جميع الاتجاهات دون ان ينكسر من جراء تعرضه لقوة الضغط . وعليه فأن المعادن القابلة للطرق (Forgable) هي التي يمكن طرقها بالمطارق او درفلتها الى اي شكل من الاشكال دون ان تتكسر ،مثل حدادة الفولاذ على الساخن و درفلته الى اي شكل من الاشكال .

ملاحظة :

ان جميع المعادن قابلة للطرق ولكن بدرجات متفاوتة ،فالنحاس أكثر قابلية للطرق من الحديد وهكذا .

3.المتانة Toughness

وترمز الى قابلية المادة على مقاومة الانهيار تحت تأثير القوى والعزوم الخارجية وتقاس متانة المعدن بعدد الكيلوغرامات التي يحتاج اليها لقطع سلك من معدن مساحة مقطعة العرضي 1 ملم2 .

ملاحظة :

متانة الحديد 77كغم /ملم2، النحاس 51 ،البلاتين 43 ،الفضة 37 ،الرصاص 2.6 .

4.قابلية الانشطار أو الانقسام Divisibility

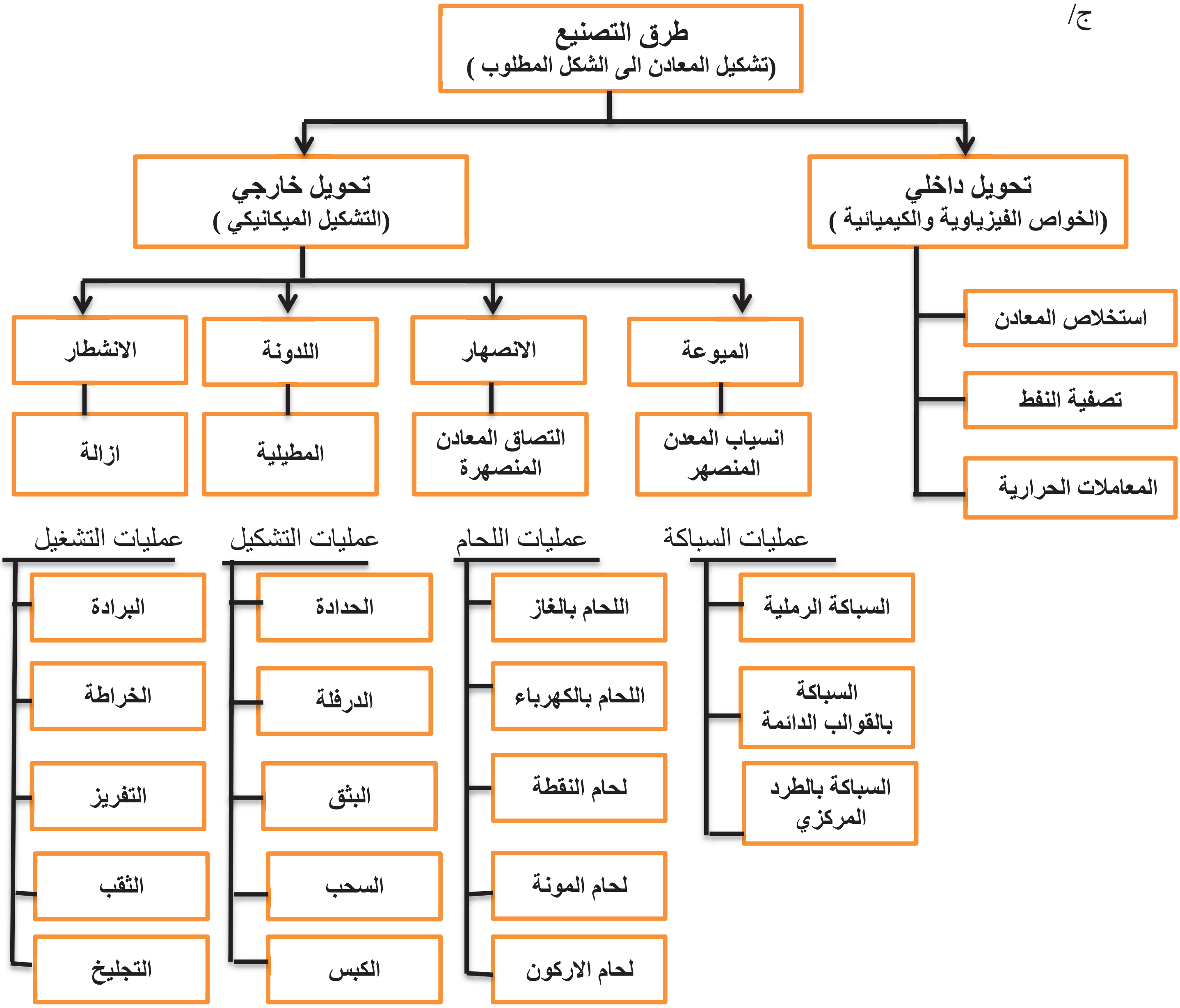
و هي قابلية المعدن على نزع اجزاء منه بطريق القص تحت تأثير الاحمال العالية كما هو الحال في عمليات ازالة الرايش المختلفة (الخراطة ،التفريز ،القشط).

5.الصلادة Hardness

و هي مقاومة المعدن لاختراق الاجسام الاخرى فيه و هذه الخاصية ضرورية للآلات القاطعة .

س/ارسم مخطط يوضح استخدام الخصائص الميكانيكية والفيزيائية في عمليات تحويل المعادن الى الاغراض المطلوبة ؟

ج/



(مخطط يوضح العلاقة بين الخواص الفيزياوية والميكانيكية وعمليات التصنيع المختلفة)

2.الاختبارات الميكانيكية Mechanical Testes

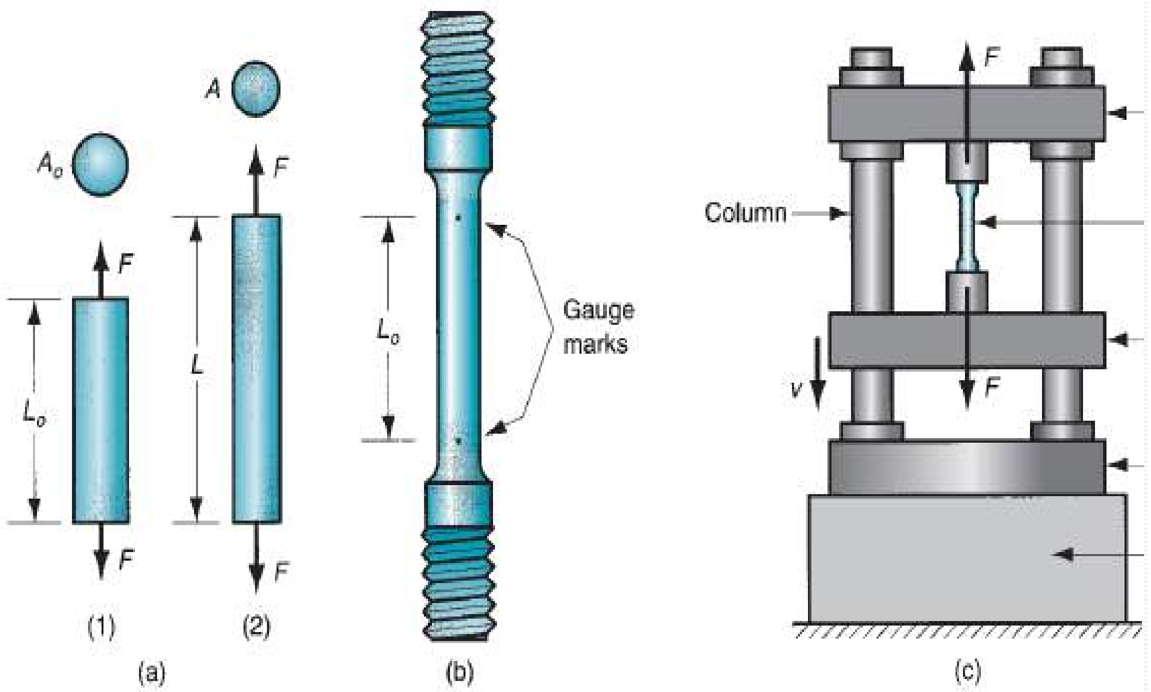
س/ما الغرض من اجراء الاختبارات الميكانيكية للمواد المعدنية ؟وما اهم هذه الاختبارات ؟

ج/
لتحديد قيم عددية تعبر عن الخواص الميكانيكية الاساسية لمعرفة خواص المواد المطلوب تصنيعها او انتاجها .
اهم الاختبارات الميكانيكية هي :

1.اختبار الشد Tension Test

س/ما الغرض من اجراء اختبار الشد ؟
ج/ يجرى اختبار الشد لتحديد خواص المتانة واللدونة (Plasticity) والمرونة (Elasticity) للمعادن .
س/ ما المقصود بـ 1.المرونة (Elasticity) 2.اللدونة (Plasticity) ؟
ج/
1.المرونة Elasticity
هي قدرة المعدن على استعادة شكله عند ازالة التحميل المسبب لتغير الشكل .(دون حدوث تشويه)
2.اللدونة Plasticity
هي قدرة المعدن على تغيير شكله وأبعاده تحت تأثير القوى الخارجية دون أن يتحطم مع احتفاظه بشكله الجديد بعد ازالة التحميل . (وجود تشويه دائمي)

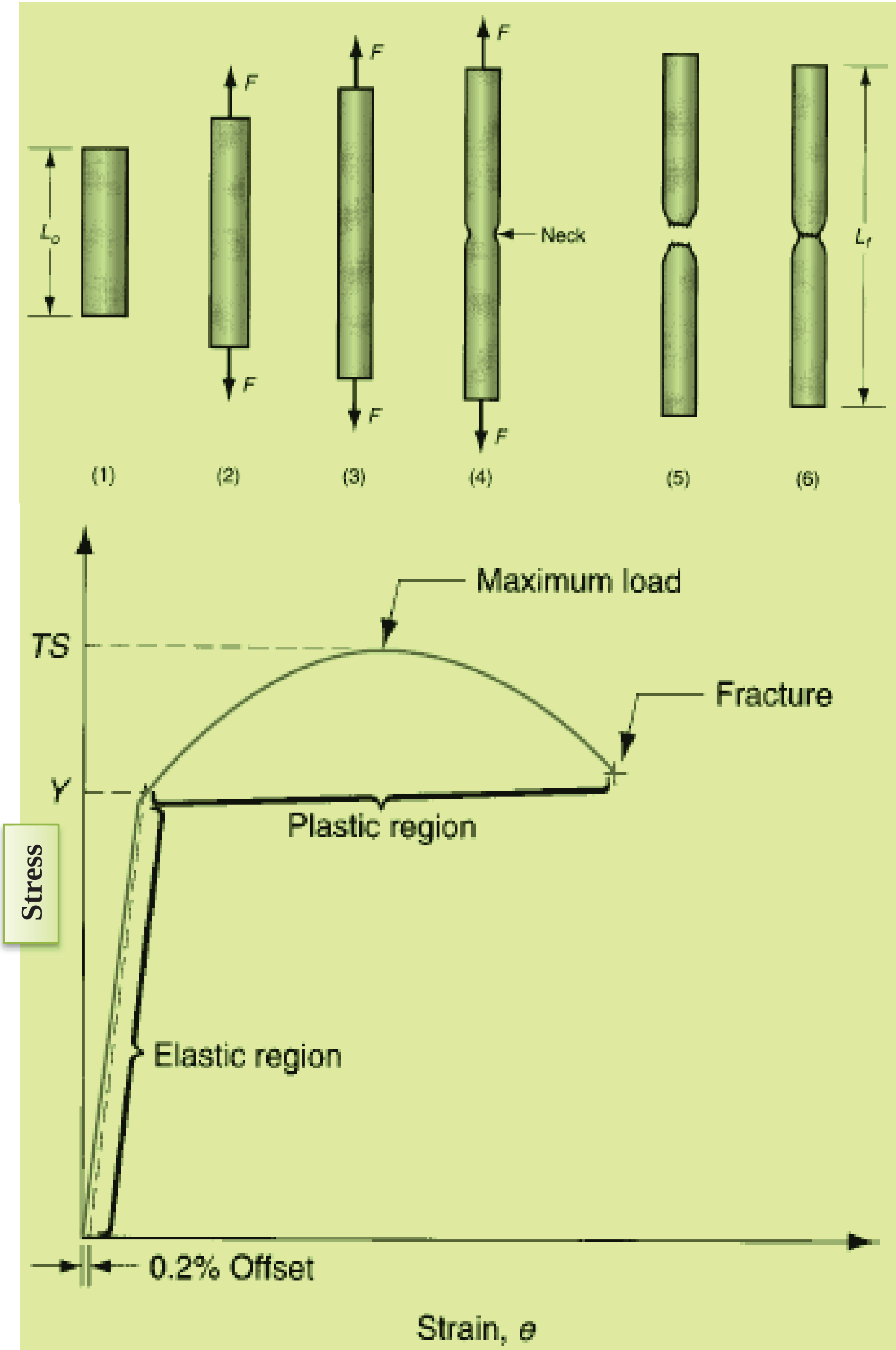
ملاحظة :
يعتبر الشد اختبارا سكونيا من حيث طريقة التحميل وعلاقة الحمل بالزمن ،وتجهز لهذا الغرض عينات نمطية ذات شكل وابعاد قياسية كما مبين في الشكل ادناه والذي يبين عينات الشد وطريقة وضعها بين فكي ماكنة الشد الخاصة التي تؤثر عليها بقوى شد متزايدة .



(شكل يوضح عينات الشد وطريقة وضعها على ماكينة الشد)

ملاحظة :

قبل بدء الفحص يتم تثبيت الطول الاصلي (L_O) والمساحة الاصلية (A_O) للنموذج وباستمرار عملية الشد تقاس الكميات الاتية :1.طول العينة (L) 2.مساحة مقطع العينة (A) 3.مقدار قوة الشد (F) وخلال الفحص ينمط (stretches)النموذج ويتعنق (necks) وفي النهاية يتعرض للكسر(fractures)ويتم تسجيل الحمل والتغير في الطول لرسم العلاقة بين الاجهاد (Stress) والانفعال (strain) وكما مبين في الشكل ادناه .



(الشكل يبين العلاقة بين الاجهاد والانفعال لنموذج يتم فحصه بطريقة الشد)

استنتاجات اختبار الشد

1.**معامل المرونة E (Modulus of elasticity) او(معامل يونج Youngs Modulus) :**

$$s_y = F_y / A_o$$

حيث :

F_y الحمل عند نقطة الخضوع (y) ويقاس بـ (N) .

3. مقاومة الشد tensile strength (TS)

وهي تساوي الحمل الاقصى للشد الذي تعرضت له العينة مقسومة على المساحة الاصلية للمقطع المستعرض ويحسب وفق العلاقة :

$$TS = \frac{Fmax}{Ao}$$

حيث:

Fmax اقصى حمل يمكن ان يتحمله المعدن قبل ان ينكسر ويقاس بـ (N) .

ملاحظة :

يمكن مقارنة قيم اجهاد الخضوع و مقاومة الشد التي يمكن الحصول عليها من اختبار الشد بالقيم المجدولة ادناه لتحديد الاختيار الملائم للمعدن المطلوب .

TABLE 3.2 Yield strength and tensile strength for selected metals.

Metal	Yield Strength MPa	Yield Strength lb/in²	Tensile Strength MPa	Tensile Strength lb/in²	Metal	Yield Strength MPa	Yield Strength lb/in²	Tensile Strength MPa	Tensile Strength lb/in²
Aluminum, annealed	28	4,000	69	10,000	Nickel, annealed	150	22,000	450	65,000
Aluminum, CW[a]	105	15,000	125	18,000	Steel, low C[a]	175	25,000	300	45,000
Aluminum alloys[a]	175	25,000	350	50,000	Steel, high C[a]	400	60,000	600	90,000
Cast iron[a]	275	40,000	275	40,000	Steel, alloy[a]	500	75,000	700	100,000
Copper, annealed	70	10,000	205	30,000	Steel, stainless[a]	275	40,000	650	95,000
Copper alloys[a]	205	30,000	410	60,000	Titanium, pure	350	50,000	515	75,000
Magnesium alloys[a]	175	25,000	275	40,000	Titanium alloy	800	120,000	900	130,000

4.معامل الرجوعية (الارتداد) Modulus of Resilience

ويساوي مقدار الطاقة المخزونة في وحدة الحجوم الناتجة من اجهاد المعدن حتى حد المرونة (Elastic Limit) اي المساحة تحت منحنى الاجهاد والانفعال حتى حد المرونة ويحسب وفق العلاقة :

$$\text{Modulus of Resilience} = \frac{(Sy)2}{2E}$$

5.معامل المتانة (T) Modulus of Toughness

ويساوي الشغل المبذول من وحدة الحجوم من المعدن حتى كسر المعدن تحت الحمل الساكن ،أي يساوي المساحة الكلية تحت منحنى الاجهاد والانفعال ويحسب وفق العلاقة :

$$T = \frac{(Fy+Fmax)\Delta L}{2AoLo}$$

ملاحظة :

من اختبار الشد يمكن تحديد:

1. نسبة الاستطالة (elongation) EL للمعادن المختلفة على وفق العلاقة المبينة ادناه:

ملاحظة :

اعتمادا على نتائج اختبار الشد نجد اختلاف المعادن في سلوكها تحت تأثير حمل الشد الاستاتيكي المحوري تبعا لطبيعة تلك المواد فمنها ما يكون :

1.معادن مطيلية (Ductile Metals) :وهي المعادن التي يمتاز منحني الاجهاد والانفعال لها بوجود منطقة مرونة (Elastic zone) ومنطقة لدونة (Plastic zone) ومنطقة بين المنطقتين هي تسمى بمنطقة الخضوع (Yield zone)،وكذلك بتكون الرقبة او العنق (Neck) .

2.معادن نصف مطيلية (Semi Ductile Metals) :وهي المعادن التي يمتاز منحني الاجهاد والانفعال لها بوجود منطقة مرونة ومنطقة لدونة ولكن دون وجود منطقة خضوع مميزة بين المنطقتين ،كما يحدث لها تشوه متوسط ،وكذلك تمتاز بتكون رقبة اقل وضوحا.

.3 معادن قصفة (Brittle Metals) :هي التي لا يوجد لها منطقة خضوع ولا يوجد لها علاقة تناسب بين الاجهاد والانفعال ،فالمنحني منذ بدايته عبارة عن خط مائل وليس خطا مستقيما ويحدث به تشوه صغير جدا مقارنة بالمواد الاخرى ،كما لا يتكون فيها رقبة ،اذ ان المعادن القصفة لا تتحمل قوى الشد لكنها في المقابل تتحمل قوى الضغط بشكل اكبر .

.4 يوجد بعض المواد تكون عالية اللدونة (Super Plastic) يزيد فيها الانفعال المرن عن نسبة 100% مثل المطاط وبعض المواد البلاستيكية.

امثلة رياضية محلولة حول اختبار الشد .

مثال 1 :

عند اختبار عينة من الصلب قطرها 10mm كان اقصى حمل تحملته هو 3140kg ،ما هو مقدار نقطة الكسر للمادة عند الشد ؟

الحل /

$$A_o = \frac{\pi D2}{4}$$
$$=78.5mm^2$$

نقطة الكسر عند الشد تحصل عند الحمل الاقصى الذي يتحمله المعدن :

$$TS = \frac{Fmax}{Ao}$$
$$= 40kg/mm^2$$

مثال 2 :

ما هو مقدار الاستطالة النسبية اذا كان الطول الحسابي للعينة قبل الاختبار هو 50mm وبعد الاختبار كان طوله 60mm ؟ الحل /

$$\textbf{Elongation\%} = \frac{\textbf{Lf}-\textbf{Lo}}{\textbf{Lo}} \times 100$$
$$= 20\%$$

أسئلة للمراجعة

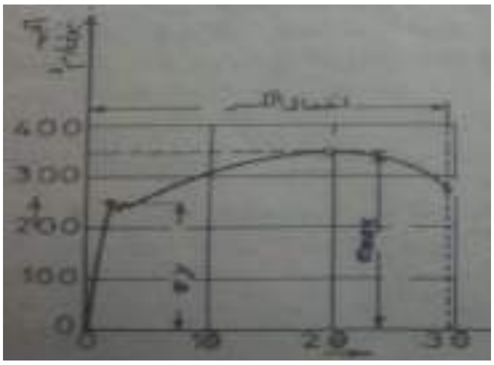
1.سلك من معدن قطره 1 cm وطولة 10 m يراد استخدامه لرفع حاويات ،اوجد اقصى حمل يمكن للسلك رفعة دون ان تزيد قيمة استطالته عن 3cm ؟ علما بأن (E) للسلك تساوي 100GPa .

2.ارسم منحني (مثالي) الاجهاد والانفعال لاختبار شد وبين عليه جميع المعلومات المفيدة .

3.باستخدام الرسم عرف :1.المطيلية Ductility .2 الرجوعية Resilience

4.عينة من الصلب طولها 50mm تم اجراء اختبار الشد لها حتى كسرت فكانت استطالتها النهائية 10mm أحسب مطيلية العينة ؟

5.أجر اختبار شد على قطعة اختبار قياسية متناسبة طويلة من الصلب الطري المعالج حراريا ذات قطر دائري 8mm و كان منحني الحمل و الاستطالة هو الموضح في الرسم المرفق ، احسب الاتي :1.معامل يونك2.أجهاد الخضوع الاعلى3.أجهاد الخضوع الادنى4.مقاومة الشد القصوى5.أجهاد الكسر6.الرجوعية7.معامل الرجوعية8.المتانة9.معامل المتانة.



2.اختبار المتانة والتقصف (اختبار مقاومة الصدمات Impact Test)

س /ما الغرض من اجراء اختبار المتانة ؟وما هي الخصائص الممكن تحديدها منه ؟

ج/

الغرض من الاختبار :

1.معرفة قابلية المادة على مقاومة الانكسار عند تعرضها للصدمات تحت ظروف التشغيل .
2.بيان تأثير تواجد الشروخ في العينات المختبرة على مقاومتها والتي تسبب ضعفا في تحمل الصدم.
3.بيان تأثير المعاملات الحرارية على المعادن وتوضيح مدى قصافتها .

ملاحظة :

هناك عدة انواع من اختبارات الصدم القياسية مثل شاربي وايزود وستارت وستانتون ،ويعد اختبار شاربي (Charpy)وايزود (Izod) هما الاختباران الاساسيان في اختبار الصدم ،ويجرى هذان الاختباران بوساطة اجهزة خاصة ،وهذه الاجهزة اما ان تكون من النوع الذي يسمى بدقاق ايزود او الذي يسمى بدقاق شاربي لاحظ الشكل ادناه والذي يمثل جهاز فحص الصدم .

(جهاز فحص الصدم)

خطوات أجراء اختبار الصدم بطريقة اختبار أيزود وشاربي

1.اختيار أشكال العينات القياسية

The cutting action of the twist drill is complex. The rotation and feeding of the drill bit result in relative motion between the cutting edges and the workpiece to form the chips. The cutting speed along each cutting edge varies as a function of the distance from the axis of rotation.

Chip removal can be a problem in drilling.

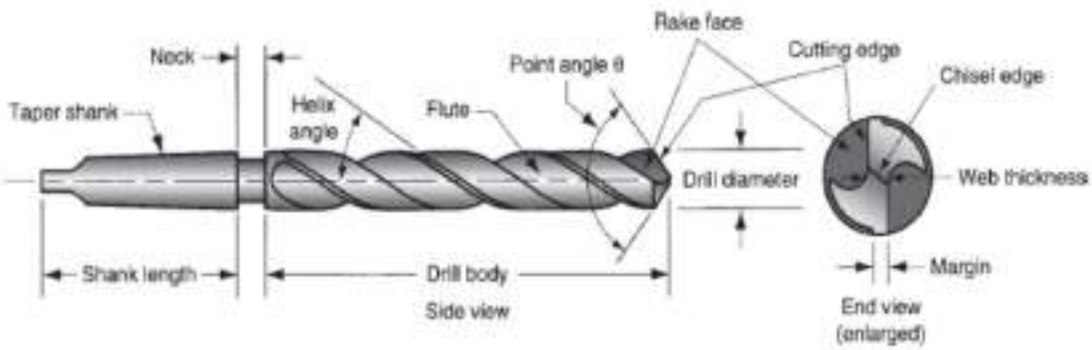


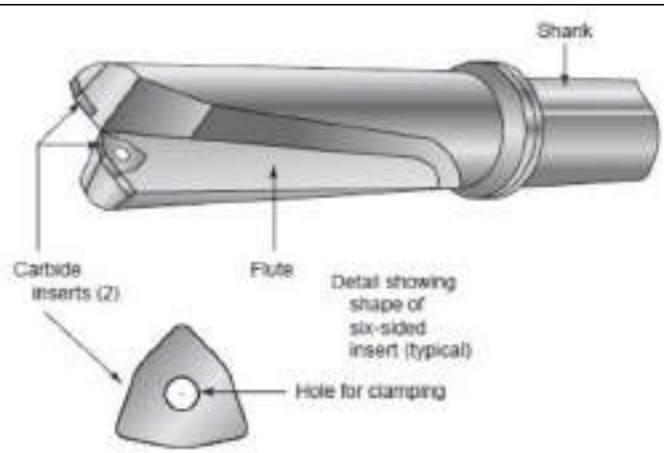
Figure 2: Standard geometry of a twist drill

Because of chip removal and heat, a twist drill is normally limited to a hole depth of about four times its diameter. Twist drills are normally made of high-speed steel.

The geometry of the drill is fabricated before heat treatment, Grinding is used to sharpen the cutting edges and shape the drill point.

Although twist drills are the most common hole-making tools, other drill types are also available. Straight-flute drills operate like twist drills except that the flutes for chip removal are straight along the length of the tool rather than spiraled. The simpler design of the straight-flute drill permits carbide tips to be used as the cutting edges, either as brazed or indexable inserts.

Figure 3 illustrates the straight-flute indexable-insert drill. The cemented carbide inserts allow higher cutting speeds and greater production rates than HSS twist drills. However, the inserts limit how small the drills can be made. Thus, the diameter range of commercially available indexable-insert drills runs from about 16 mm to about 127 mm.



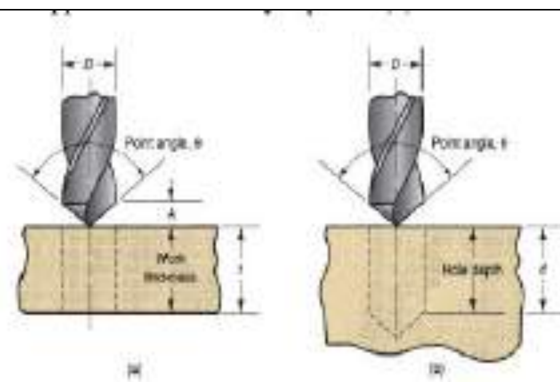


Figure 4: Two hole types: (a) through hole and (b) blind hole.

Example: A drilling operation is performed to create a through hole on a steel plate that is 15 mm thick. Cutting speed = 0.5 m/s, and feed = 0.22 mm/rev. The 20-mm diameter twist drill has a point angle of 118°. Determine (a) the machining time and (b) metal removal rate once the drill reaches full diameter.

Solution: (a)

$N = v/\pi D = 0.5(103)/ \pi(20) = 7.96$ rev/s

$f_r = N f = 7.96(0.22) = 1.75$ mm/s

$A = 0.5(20) \tan (90 - 118/2) = 6.01$ mm

$Tm = (t + A)/f_r = (15 + 6.01)/1.75 = 12.0$ s = **0.20 min**

(b)

$RMR = \pi (20)^2(1.75)/4 =$ **549.8 mm³/s**

OPERATIONS RELATED TO DRILLING

Several operations related to drilling are illustrated in Figure 5 and described in this section. Most of the operations follow drilling; a hole must be made first by drilling, and then the hole is modified by one of the other operations. Centering and spot facing are exceptions to this rule. All of the operations use rotating tools.

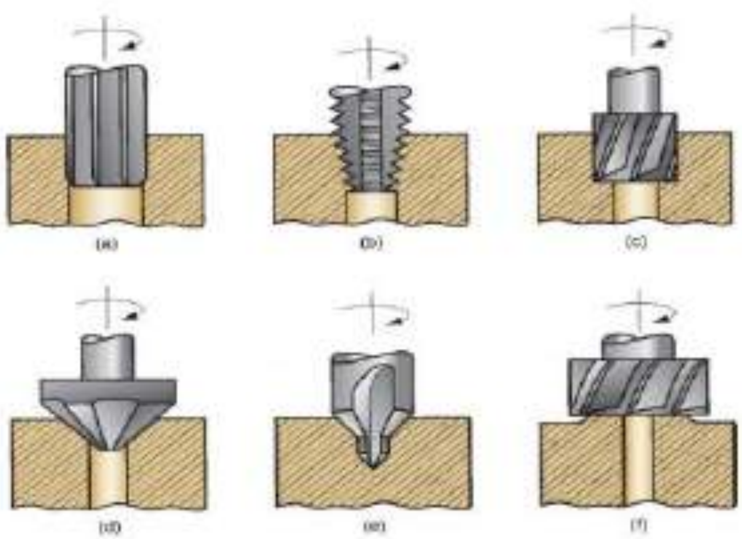


Figure 5: Machining operations related to drilling: (a) Reaming, (b) Tapping, (c) Counterboring, (d) Countersinking, (e) Centering, and (d) Spot facing

(a) *Reaming*. Reaming is used to slightly enlarge a hole, to provide a better tolerance on its diameter, and to improve its surface finish. The tool is called a *reamer*, and it usually has straight flutes.

(b) *Tapping*. This operation is performed by a *tap* and is used to provide internal screw threads on an existing hole.

(c) *Counterboring*. Counterboring provides a stepped hole, in which a larger diameter follows a smaller diameter partially into the hole. A counterbored hole is used to seat a bolt head into a hole so the head does not protrude above the surface.

(d) *Countersinking*. This is similar to counterboring, except that the step in the hole is cone-shaped for fl at head screws and bolts.

(e) *Centering*. Also called center drilling, this operation drills a starting hole to accurately establish its location for subsequent drilling. The tool is called a *center drill*.

(f) *Spot facing*. Spot facing is similar to milling. It is used to provide a flat machined surface on the work part in a localized area.

Disadvantages of Machining

- Wasteful of material
  - *Chips generated in machining are wasted material, at least in the unit operation*
- Time consuming
  - *A machining operation generally takes more time to shape a given part than alternative shaping processes, such as casting, powder metallurgy, or forming*

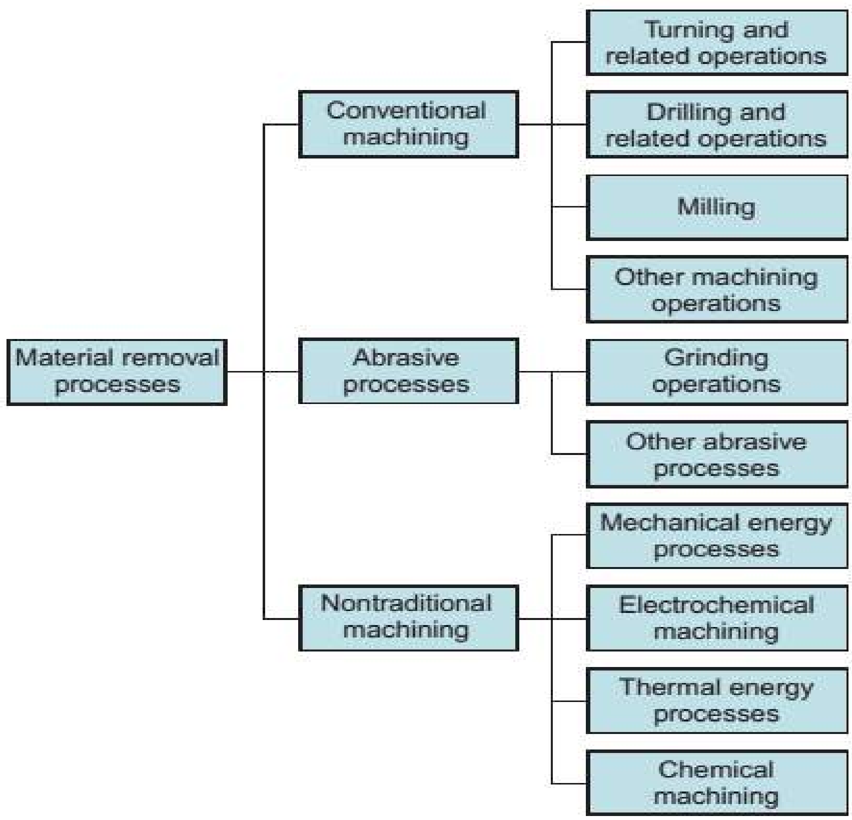


FIGURE 21.1
Classification of material removal processes.

https://www.youtube.com/watch?v=uQPCdwegXzc&t=696s

https://www.youtube.com/watch?v=wIOdOkse0Cw

https://www.youtube.com/watch?v=aeOaAZRwpfY

Machining Tools

Most modern cutting tool materials are ceramic or composite materials designed to be **very hard**.

1. *Single-Point Tools*
   - One cutting edge
   - *Turning* uses single point tools
   - Point is usually rounded to form a *nose radius*
2. *Multiple Cutting Edge Tools*
   - More than one cutting edge
   - Motion relative to work usually achieved by rotating
   - *Drilling* and *milling* use rotating multiple cutting edge tools.

Single point

Multiple point

Cutting Conditions

Relative motion is required between the tool and work to perform a machining operation. The primary motion is accomplished at a certain cutting speed v. In addition, the tool must be moved laterally across the work. This is a much slower motion, called the feed f. The remaining dimension of the cut is the penetration of the

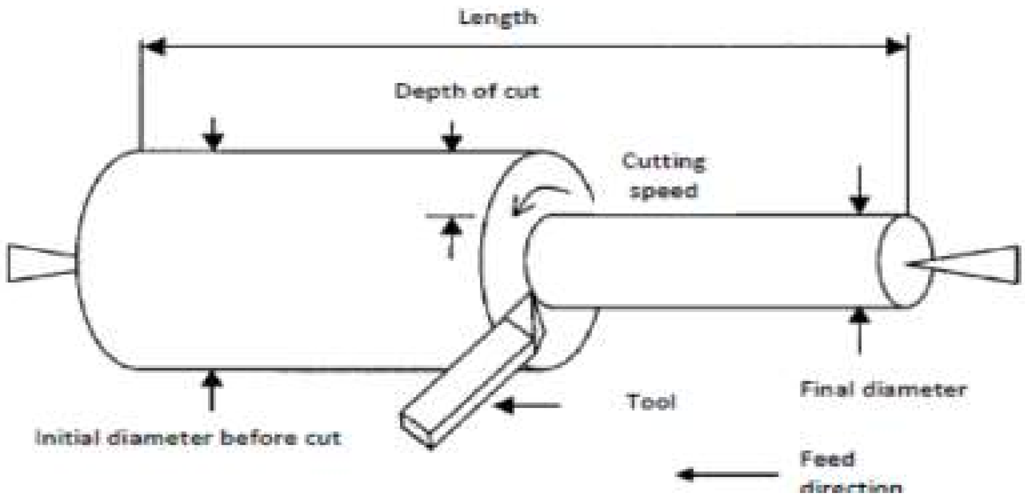
Cutting tool below the original work surface, called the depth of cut d. collectively, speed, feed, and depth of cut are called the cutting conditions. They form the three dimensions of the machining process, and for certain operations (e.g., most single-point tool operations) they can be used to calculate the material removal rate for the process:

$$R_{MR} = vfd$$

where R_{MR} = material removal rate, mm^3/s (in^3/min); v = cutting speed, m/s (ft/min), which must be converted to mm/s (in/min); f = feed, mm (in); and d = depth of cut, mm (in).

CUTTING CONDITIONS IN TURNING

Lathe is the father of all machine tools. Lathe removes unwanted material from apiece of work to give it the required shape and size. The workpiece is rotated at the desired speed and the tool removes the metal in the form of chips.



The cutting tool may be fed in any direction relative to the work. If the tool moves parallel to the axis of rotation of the work a cylindrical surface is produced. And if the tool moves in a direction perpendicular to the axis of the lathe a flat surface is produced. Conical and curved surfaces can be produced on a lathe too.

Lathe operations:

Before studying the various operations, we must study the cutting speed, feed and depth of cut:

CUTTING CONDITIONS IN TURNING

The rotational speed in turning is related to the desired cutting speed at the surface of the cylindrical workpiece by the equation

$$N = \frac{V}{\pi D_o}$$

Where N = rotational speed, rev/min; v = cutting speed, m/min (ft/min); and

D_o = original diameter of the part, m.

The turning operation reduces the diameter of the work from its original diameter Do to a final diameter Df, as determined by the depth of cut d:

$Df = D_o - 2d$

The feed in turning is generally expressed in mm/rev. This feed can be converted to a linear travel rate in mm/min by the formula

$f_r = N f$

Where *fr* = feed rate, mm/min; and *f* = feed, mm/rev.

There are three types of feed:

1- Longitudinal feed. Tool moves parallel to the axis of lathe.

2- Cross feed. Tool moves normal to the lathe axis.

3- Angular feed. Tool moves at an angle to the lathe axis.

The time to machine from one end of a cylindrical work part to the other is

given by $T_m = L/f_r$

Where *Tm* = machining time, min; and *L* = length of the cylindrical workpart, mm. A more direct computation of the machining time is provided by the following equation:

$$T_m = \frac{\pi D_o L}{fv}$$

Where *Do* = work diameter, mm ; *L* =work part length, mm ; *f* = feed, mm/rev ; and *v* = cutting speed, mm/min . As a practical matter, a small distance is usually added to the work part length at the beginning and end of the piece to allow for approach and overtravel of the tool. Thus, the duration of the feed motion past the work will be longer than *Tm*. The volumetric rate of material removal can be most conveniently determined by the following equation:

$$MRR = v\,f\,d$$

Where *MRR* = material removal rate, mm3/min . In using this equation, the units for *f* are expressed simply as mm, in effect neglecting the rotational character of turning. Also, care must be exercised to ensure that the units for speed are consistent with those for *f* and *d*. Example: A turning operation is performed on a cylindrical work part whose diameter = 120 mm and length = 450 mm. Cutting speed = 2.0 m/s, feed =0.25 mm/rev, and depth of cut =2.2 mm. Determine (a) cutting time and (b) material removal rate.

a) $$T_m = \frac{\pi D_o L}{fV} = \frac{\pi(120)(450)}{(0.25)(2000)} = 5.65 \text{ min}$$

b) $$MRR = v\,f\,d = 2000(0.25)\,(2.2) = 1100 \text{ mm}^3/\text{s}$$

Example: A cylinder of 155 mm diameter is to be reduced to 150mm diameter in one turning cut with a feed of 0.15mm/rev and a cutting speed of 150m/min.Find the spindle speed, feed rate and metal removal rate.

$$D_{av} = \frac{155+150}{2} = 152.5\text{mm}$$

The cutting speed, Vis obtained as

$$V = \frac{\pi D_{av} N}{1000} \quad m/\min$$

Its gives spindle speed, N as

$$N = \frac{150*1000}{\pi*152.5} = \mathbf{313\ rpm}$$

The feed rate, f_m is obtained as

$$f_m = f_r * N$$

$$= \frac{0.15*313}{60} = \mathbf{0.7825\ mm/s}$$

The depth of cut, d is expressed as

$$d = \frac{155-150}{2} = 2.5\ \text{mm}$$

The metal removal rate can be obtained as

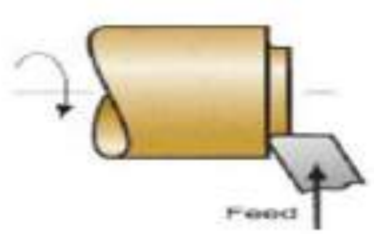
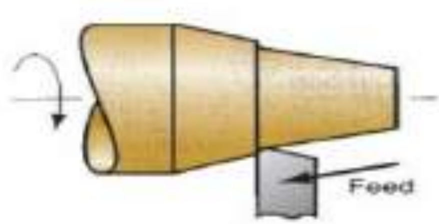
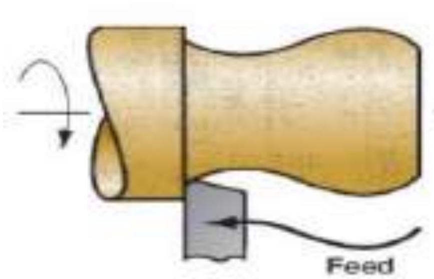
$$= \frac{\pi * f_r * N * D_{av} * d}{60} \ \text{mm}^3/\text{s}$$

$$= \frac{\pi*0.15*313*152.5*2.5}{60} = \mathbf{937.22\ mm^3/s}$$

OPERATIONS RELATED TO TURNING

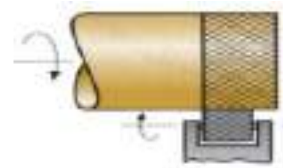
A variety of other machining operations can be performed on a lathe in addition to turning; these include the following, illustrated in Figure :

(a) *Facing*. The tool is fed radially into the rotating work on one end to create a flat surface on the end.

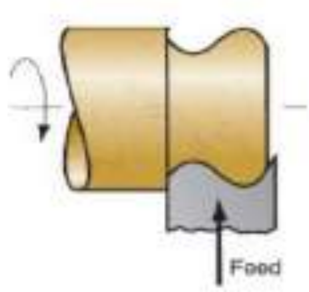
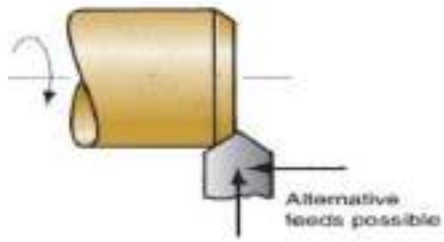
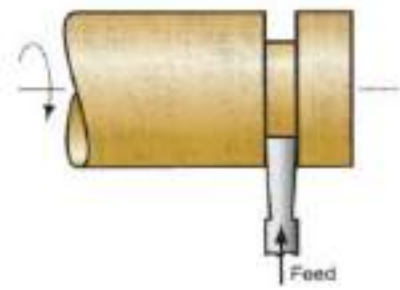
		
a	b	c

(b) *Taper turning*. Instead of feeding the tool parallel to the axis of rotation of the work, the tool is fed at an angle, thus creating a tapered cylinder or conical shape.

(c) *Contour turning*. Instead of feeding the tool along a straight line parallel to the axis of rotation as in turning, the tool follows a contour that is other than straight, thus creating a contoured form in the turned part.



(d) *Form turning*. In this operation, sometimes called *forming*, the tool has a shape that is imparted to the work by plunging the tool radially into the work.

		
d	**e**	**f**

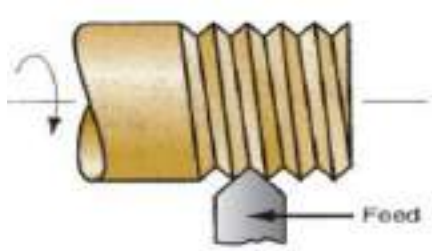
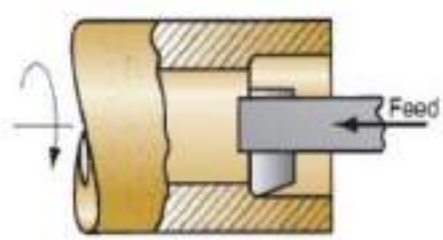
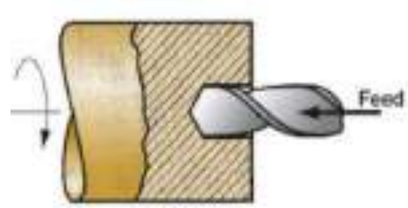
(e) *Chamfering*. The cutting edge of the tool is used to cut an angle on the corner of the cylinder, forming a "chamfer."

(f) *Cutoff*. The tool is fed radially into the rotating work at some location along its length to cut off the end of the part. This operation is sometimes referred to as *parting*.

(g) *Threading*. A pointed tool is fed linearly across the outside surface of the rotating work part in a direction parallel to the axis of rotation at a large effective feed rate, thus creating threads in the cylinder.

(h) *Boring*. A single-point tool is fed linearly, parallel to the axis of rotation, on the inside diameter of an existing hole in the part.

(i) *Drilling*. Drilling can be performed on a lathe by feeding the drill into the rotating work along its axis. *Reaming* can be performed in a similar way.

		
g	**h**	**i**

(j) *Knurling*. This is not a machining operation because it does not involve cutting of material. Instead, it is a metal forming operation used to produce a regular cross-hatched pattern in the work surface.

Taper Turning

- Taper - Uniform change in diameter along the length of work piece

• Taper turning - Operation of producing conical surface on cylindrical work piece

• Taper specified by conicity (K) – ratio of difference in diameters of taper to its length:

K=(D-d)/L

Taper Turning - Methods

• Form tool method

• Tail stock method

• Compound rest method

• Taper turning attachment method

Conicity: D – Large diameter of taper, d – Small diameter of taper, L – Length of taper α - Half taper angle

22.1 A cylindrical workpart 200 m
Cutting speed = 2.30 m/s, fee
time, and (b) metal removal r

Solution: (a) $N = v/(\pi D) = (2.$
$f_r = Nf = 6.366(.3) = 1.17$ mm
$T_m = L/f_r = 700/1.17 = 598$ s =

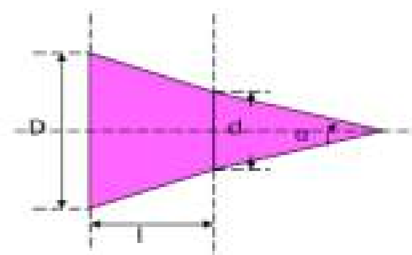
Alternative calculation using

(b) $R_{MR} = vfd = (2.30$ m/s$)(10$

22.2 In a production turning operat
the cylindrical workpiece in 5
feed = 0.30 mm/rev and a dep
machining time requirement?

Solution: Starting with Eq. (2
Rearranging to determine cutt
$v = \pi(0.4)(0.15)/(0.30)(10^{-3})(5$

$$K = \frac{D-d}{L}$$



A cylindrical work bar with 4.5 in diameter and 52 in length is chucked in an engine lathe and supported at the opposite end using a live center. A 46.0 in portion of the length is to be turned to a diameter of 4.25 in one pass at a speed of 450 ft/min. The metal removal rate should be 6.75 in^3/min. Determine (a) the required depth of cut, (b) the required feed, and (c) the cutting time.

Solution: (a) depth $d = (4.50 - 4.25)/2 =$ **0.125 in**

(b) $R_{MR} = vfd$; $f = R_{MR}/(12vd) = 6.75/(12 \times 450 \times 0.125) = 0.010$ in

$f =$ **0.010 in/rev**

(c) $N = v/\pi D = 450 \times 12/4.5\pi = 382$ rev/min

$f_r = 382(0.010) = 3.82$ in/min

$T_m = 46/3.82 =$ **12.04 min**

Milling process

Milling is a machining operation in which a work part is fed past a rotating cylindrical tool with multiple cutting edges, (In rare cases, a tool with one cutting edge, called a ***fly-cutter***, is used). The axis of rotation of the cutting tool is perpendicular to the direction of feed.

This orientation between the tool axis and the feed direction is one of the features that distinguishes milling from drilling. In drilling, the cutting tool is fed in a direction parallel to its axis of rotation.

The cutting tool in milling is called a ***milling cutter*** and the cutting edges are called teeth. The conventional machine tool that performs this operation is a ***milling machine***. The geometric form created by milling is a plane surface. Other work geometries can be created either by means of the cutter path or the cutter shape. Owing to the variety of shapes possible and its high production rates, milling is one of the most versatile and widely used machining operations.

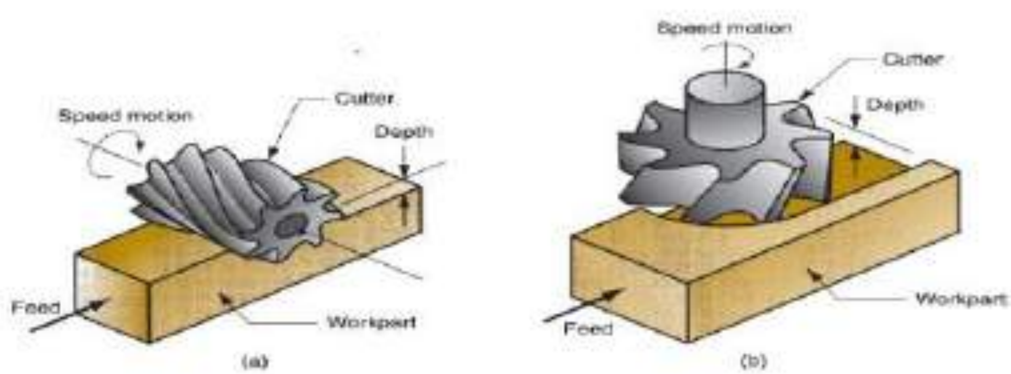


Figure 1: Two basic types of milling operations: a) peripheral or plain milling, b) face milling

Milling is an *interrupted cutting* operation; the teeth of the milling cutter enter and exit the work during each revolution. This interrupted cutting action subjects the teeth to a cycle of impact force and thermal shock on every rotation. The tool material and cutter geometry must be designed to withstand these conditions.

TYPES OF MILLING OPERATIONS

There are two basic types of milling operations, shown in Figure 1: (a) peripheral milling and (b) face milling. Most milling operations create geometry by generating the shape.

Peripheral Milling In peripheral milling, also called *plain milling*, the axis of the tool is parallel to the surface being machined, and the operation is performed by cutting edges on the outside periphery of the cutter. Several types of peripheral milling are shown in Figure 2:

(a) *slab milling*, the basic form of peripheral milling in which.

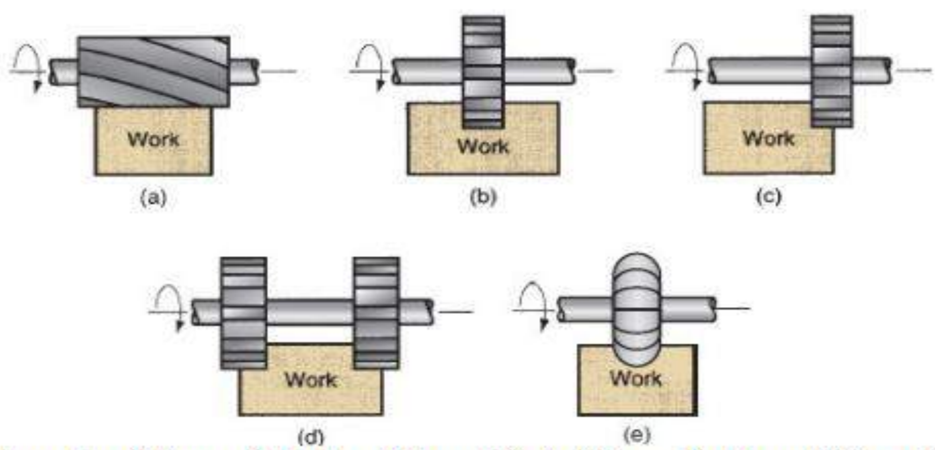


Figure 2: peripheral milling :a) slab milling, b) slotting, c) side milling, d) straddle milling, and e) form milling.

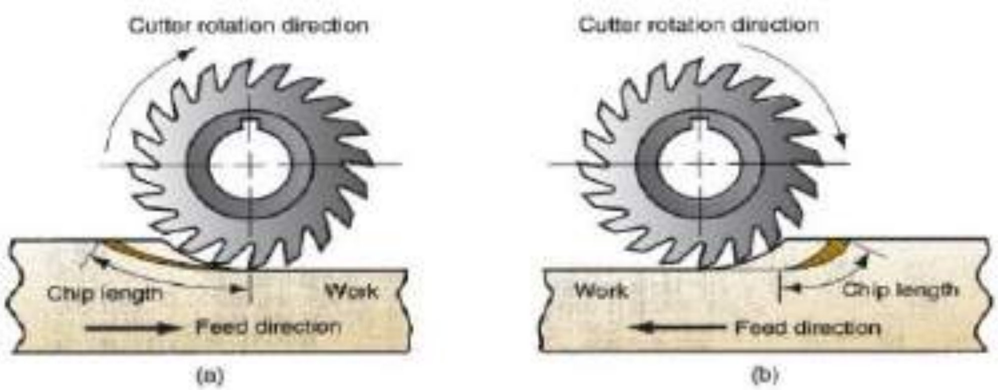


Figure 3: Two forms of peripheral milling operation with 20 tooth cutter: a) up milling, b) down milling

The cutter width extends beyond the workpiece on both sides; (b) *slotting*, also called *slot milling*, in which the width of the cutter is less than the workpiece width, creating a slot in the work—when the cutter is very thin, this operation can be used to mill narrow slots or cut a work part in two, called *saw milling*; (c) *side milling*, in which the cutter machines the side of the workpiece; (d) *straddle milling*, the same as side milling, only cutting takes place on both sides of the work; and (e) *form milling*, in which the milling teeth have a special profi le that determines the shape of the slot that is cut in the work.

In peripheral milling, the direction of cutter rotation distinguishes two forms of milling: up milling and down milling, illustrated in Figure 3. In *up milling*, also called *conventional milling*, the direction of motion of the cutter teeth is opposite the feed direction when the teeth cut into the work. It is milling "against the feed." In *down milling*, also called *climb milling*, the direction of cutter motion is the same as the feed direction when the teeth cut the work.

It is milling "with the feed." The relative geometries of these two forms of milling result in differences in their cutting actions. In up milling, the chip formed by each cutter tooth starts out very thin and increases in thickness during the sweep of the cutter. In down milling, each chip starts out thick and reduces in thickness throughout the cut. The length of a chip in down milling is less than in up milling (the difference is exaggerated in the figure).

This means that the cutter is engaged in the work for less time per volume of material cut, and this tends to increase tool life in down milling. The cutting force direction is tangential to the periphery of the cutter for the teeth that are engaged in the work. In up milling, this has a tendency to lift the work part as the cutter teeth exit the material. In down milling, this cutter force direction is downward, tending to hold the work against the milling machine table. Face Milling In face milling, the axis of the cutter is perpendicular to the surface being milled, and machining is performed by cutting edges on both the end and outside periphery of the cutter. As in peripheral milling, various forms of face milling exist, several of which are shown in Figure 4: (a) *conventional face milling*, in which the diameter of the cutter is greater than the work part width, so the cutter overhangs the work on both sides; (b) *partial face milling*, where the cutter overhangs the work on only one side; (c) *end milling*, in which the cutter diameter is less than the work width, so a slot is cut into the part; (d) *profile milling*, a form of end milling in which the outside periphery of a flat part is cut; (e) *pocket milling*, another form of end milling used

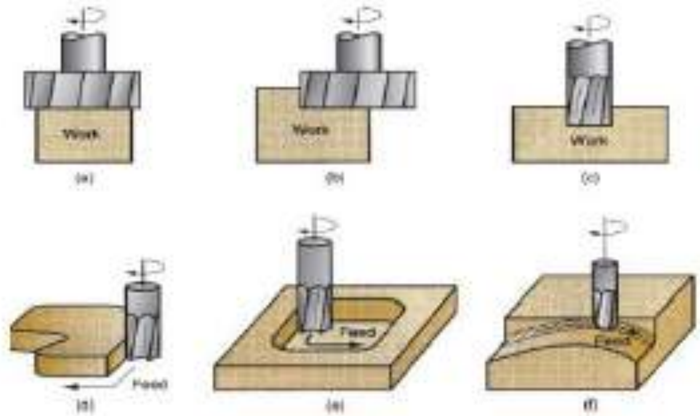


Figure 4: Face milling : a) conventional face milling, b) partial face milling, c) end milling, d) profile milling, e) pocket milling, f) surface contouring.

To mill shallow pockets into flat parts; and (f) *surface contouring*, in which a ball-nose cutter (rather than square-end cutter) is fed back and forth across the work along a curvilinear path at close intervals to create a three-dimensional surface form. The same basic cutter control is required to machine the contours of mold and die cavities, in which case the operation is called *die sinking*.

CUTTING CONDITIONS IN MILLING

The cutting speed is determined at the outside diameter of a milling cutter. This can be converted to spindle rotation speed using a formula that should now be familiar:

$N = V/\pi D$ ……………………………………………..(1)

The feed *f* in milling is usually given as a feed per cutter tooth; called the ***chip load***, it represents the size of the chip formed by each cutting edge. This can be converted to feed rate by taking into account the spindle speed and the number of teeth on the cutter as follows:

$f_r = N n_t f$ ……………………………………………...(2)

Where f_r= feed rate, mm/min; N = spindle speed, rev/min; n_t= number of teeth on the cutter; and f = chip load in mm/tooth.

Material removal rate in milling is determined using the product of the cross sectional area of the cut and the feed rate. Accordingly, if a slab-milling operation is cutting a workpiece with width *w* at a depth *d*, the material removal rate is

$MRR = w\, d\, f_r$ …………………………………………… (3)

This neglects the initial entry of the cutter before full engagement. Equation (3) can be applied to end milling, side milling, face milling, and other milling operations, making the proper adjustments in the computation of crosssectional area of cut.

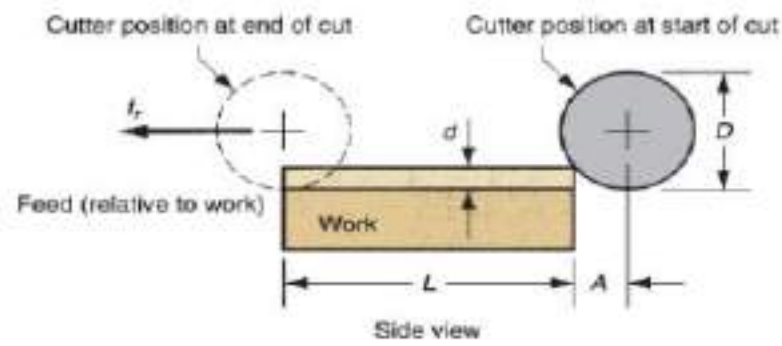


Figure 5: Slab (peripheral) milling showing entry of cutter into the workpiece

The time required to mill a workpiece of length *L* must account for the approach distance required to fully engage the cutter. First, consider the case of slab milling, Figure 5. To determine the time to perform a slab milling operation, the approach distance *A* to reach full cutter depth is given by

$A = \sqrt{d(D - d)}$ …………………………………………… (4)

Where *d* = depth of cut, mm; and *D* = diameter of the milling cutter, mm.

The time *Tm* in which the cutter is engaged milling the workpiece is

$T_m=(L+A)/f_r$…………………………………………… (5)

For face milling, consider the two possible cases pictured in Figure 6. The first case is when the cutter is centered over a rectangular workpiece as in Figure 6(a).

The cutter feeds from right to left across the workpiece. In order for the cutter to reach the full width of the work, it must travel an approach distance given by

$A = 0.5(D - \sqrt{D^2 - w^2})$ …………………………………… (6)

Where *D* = cutter diameter, mm and *w* = width of the workpiece, mm. If *D* = *w*, then Equation (6) reduces to *A* = 0.5*D*. And if *D* < *w*, then a slot is cut into the work and *A* = 0.5*D*.

The second case is when the cutter is offset to one side of the work, as in Figure 6 (b). In this case, the approach distance is given by

$A = \sqrt{w(D - w)}$ .... (7)

Where *w* = width of the cut, mm. In either case, the machining time is given by

$T_m=(L+A)/f_r$……………………………………….. (8)

It should be emphasized in all of these milling scenarios that *Tm* represents the time the cutter teeth are engaged in the work, making chips. Overtravel distances are usually added at the beginning and end of each cut to allow access to the work for loading and unloading. Thus the actual duration of the cutter feed motion is likely to be greater than *Tm*.

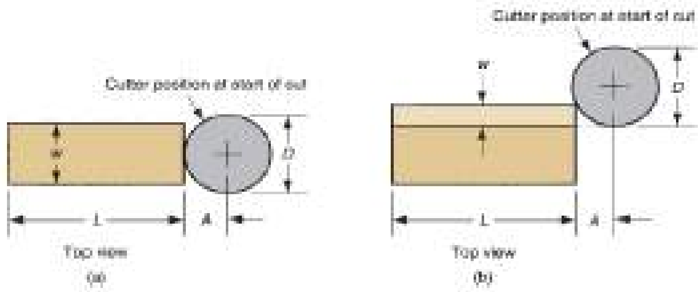


Figure 6: Face milling showing approach and overtravel distance for two cases: (a) when cutter is centered over the workpiece, and (b) when cutter is offset to one side over the work.

Example: A peripheral milling operation is performed on a rectangular workpiece that is 320 mm long by 60 mm wide by 56 mm thick. The 65-mmdiameter milling cutter has 4 teeth, is 80 mm long, and overhangs the work on either side by 10 mm. The operation reduces the thickness of the piece to 50 mm. Cutting speed = 0.50 m/s and chip load = 0.24 mm/tooth. Determine (a) machining time and (b) metal removal rate once the cutter reaches full depth.

Solution: (a)

$N = v/\pi D = 0.50(10^3)/\pi(65) = 2.45$ rev/s

$f_r = N\, n_t f = 2.45(4)(0.24) = 2.35$ mm/s

Depth of cut $d = 56 - 50 = 6$ mm

$A = (6(65 - 6))^{0.5} = 18.8$ mm

$T_m = (320 + 18.8)/2.35 = 144.2$ s $= \mathbf{2.40\ min}$

(b)

$MRR = w\, d\, f_r = 60(6)(2.35) = \mathbf{846\ mm^3/s}$

MILLING MACHINES

Milling machines must provide a rotating spindle for the cutter and a table for fastening, positioning, and feeding the work part. Various machine tool designs satisfy these requirements. To begin with, milling machines can be classified as horizontal or vertical. A ***horizontal milling machine*** has a horizontal spindle, and this design is well suited for performing peripheral milling (e.g., slab milling, slotting, side and straddle milling) on work parts that are roughly cube shaped. **A *vertical milling machine*** has a vertical spindle, and this orientation is appropriate for face milling, end milling, surface contouring, and die-sinking on relatively flat work parts. Other than spindle orientation, milling machines can be classified into the following types: (1) knee-and-column, (2) bed type, (3) planer type, (4) tracer mills, and (5) CNC milling machines.

CNC milling machines are milling machines in which the cutter path is controlled by alphanumerical data rather than a physical template. They are especially suited to profile milling, pocket milling, surface contouring, and die sinking operations, in which two or three axes of the worktable must be simultaneously controlled to achieve the required cutter path. An operator is normally required to change cutters as well as load and unload work parts.

example, rotating in steps) to effect the desired shape change. Open-die forging process is shown in the following Figure.

The skill of the human operator is a factor in the success of these operations. An example of open-die forging in the steel industry is the shaping of a large, square cast ingot into a round cross section. Open-die forging operations produce rough forms, and subsequent operations are required to refine the parts to final geometry and dimensions

Advantages and Limitations

Advantages

1-Simplest type of forging

2-Dies are inexpensive

3-Wide range of part sizes, ranging from 30-1000lbs

4-Good strength qualities

5-Generally good for small quantities

Limitations

1-Simple shapes only

2-difficult to hold close tolerances

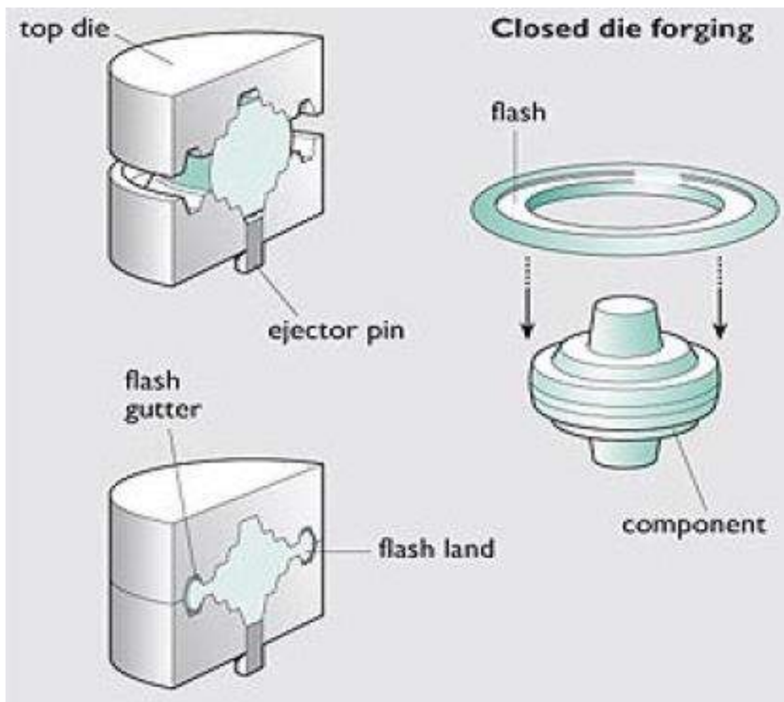
3-machining necessary

4-low production rate

5-poor utilization of material

6-high skill required

Impression or Close Die Forging



Impression die forging

In impression-die forging, so0metimes called closed die forging, the die surfaces contain a shape or impression that is imparted to the work during compression, thus constraining metal flow to a significant degree as shown in following Figure. In this type of operation, a portion of the work metal flows beyond the die impression to form flash and must be trimmed off later. The process is shown in the following Figure as a three step sequence. The raw work piece is shown as a cylindrical part similar to that used in the previous open-die operation.

Advantages and Limitations

Advantages

1-Good utilization of material

2-Better properties than Open Die Forgings

3-Dies can be made of several pieces and inserts to create more advanced parts

4-Presses can go up to 50,000 ton capacities

5-Good dimensional accuracy

6-High production rates

7-Good reproducibility

Limitations

1-High die cost

2-Machining is often necessary

3-Economical for large quantities, but not for small quantities

EXTRUSION:-

Extrusion is a process that forces metal or plastic to flow through a shaped opening die. The material is plastically deformed under the compression in the die cavity. The process can be carried out hot or cold depending on the ductility of the material.

The **tooling cost** and **setup** is expensive for the extrusion process, but the actual manufactured part cost is inexpensive when produced in significant quantities.

Materials that can be extrudes are aluminum, copper, steel, magnesium, and plastics. Aluminum, copper and plastics are most suitable for extrusion.

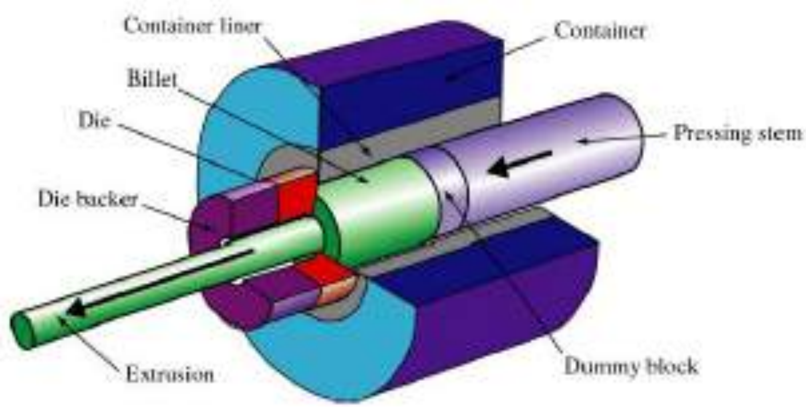
Classification of extrusion processes:-

There are several ways to classify metal extrusion processes

1- By direction • Direct / Indirect extrusion

2- By operating temperature • Hot / cold extrusion
3- By equipment • Horizontal and vertical extrusion
4- Hydrostatic Extrusion: Pressure is applied by a piston through incompressible fluid medium surrounding the billet

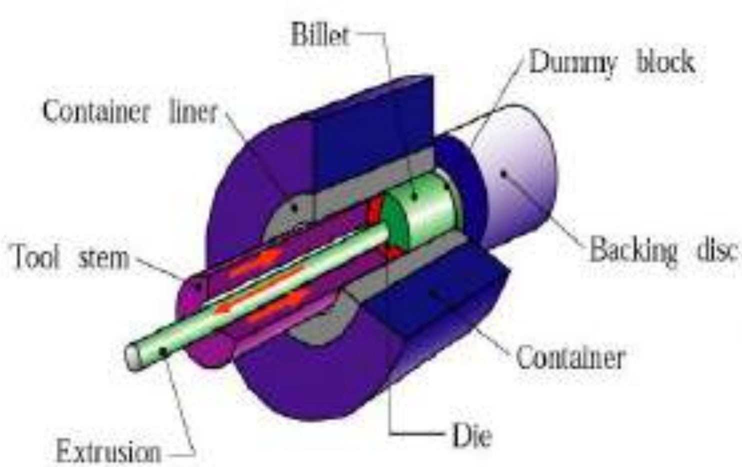
Direct Extrusion: In this extrusion process, the heated billet is placed in the container. A ram towards the die pushes it. The metal is subjected to plastic deformation, slides along the walls of the container and is forced to flow through the Die opening. At the end of the extruding operation, a small piece of metal, called Butt-end scrap, remains in the container and cannot be extruded. Direct extrusion Process is shown in the following Figure



Indirect Extrusion: For the production of solid part, the die is mounted on the end of a hollow ram and enters the container as shown in the following Figure, the outer end of container being closed by a closure plate. As the ram travels, the die applies pressure on the billet and the deformed metal flows through the die opening in the direction opposite to the ram motions and the product is extruded through the hollow ram. In indirect extrusion, there is practically no slip of billet with respect to the container walls.

Cold extrusion

Cold extrusion is the process done at room temperature or slightly elevated temperatures. This process can be used for most materials-subject to designing robust enough tooling that can withstand the stresses created by extrusion.



Advantages

• No oxidation takes place.

• Good mechanical properties due to severe cold working as long as the temperatures created are below the recrystallization temperature.

• Good surface finish with the use of proper lubricants.

Hot extrusion

Hot extrusion is done at fairly high temperatures, approximately 50 to 75 % of the melting point of the metal. The pressures can range from 35-700 MPa (5076 - 101,525 psi). • The most commonly used extrusion process is the hot direct process. The cross-sectional shape of the extrusion is defined by the shape of the die.

• Due to the high temperatures and pressures and its detrimental effect on the die life as well as other components, good lubrication is necessary. Oil and graphite work at lower temperatures, whereas at higher temperatures glass powder is used.

Horizontal extrusion presses

(15- 50 MN capacity or up to 140 MN)

• Used for most commercial extrusion of bars and shapes

Vertical extrusion presses

(3- 20 MN capacity)

Chiefly used in the production of thin-wall tubing.

Drawing of rods, wires and tubes:-

Introduction

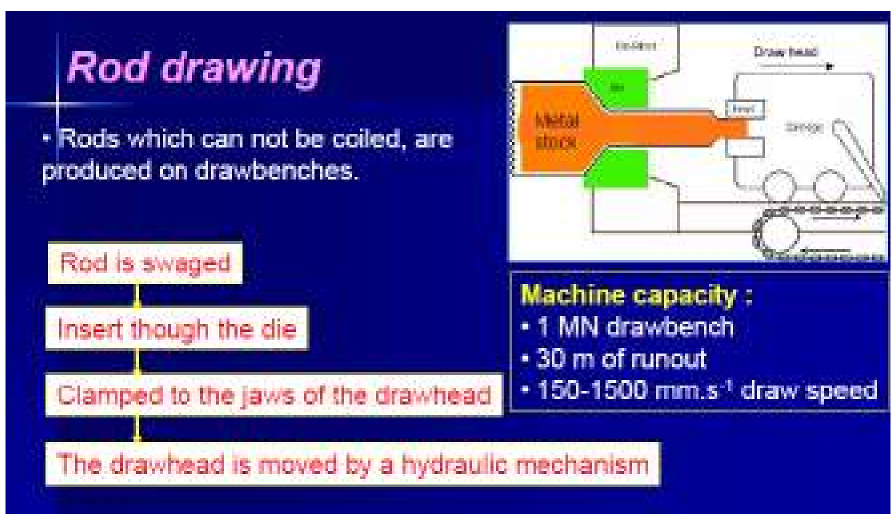
• Drawing operations involve pulling metal through a die by means of a tensile force applied to the exit side of the die.

• The plastic flow is caused by compression force, arising from the reaction of the metal with the die.

• Starting materials: hot rolled stock (ferrous) and extruded (nonferrous).

• Material should have high ductility and good tensile strength.

*Bar wire and tube drawing are usually carried out at room temperature, except for large deformation, which leads to considerable rise in temperature during drawing.



• The metal usually has a circular symmetry (but not always, depending on requirements).

Rod and wire drawing:-

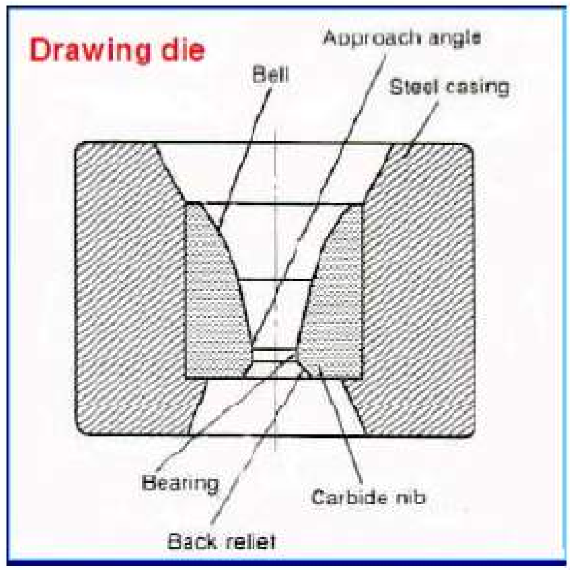
• Reducing the diameter through plastic deformation while the volume remains the same.

• Same principals for drawing bars, rods, and wire but equipment is different in sizes depending on products.

Wire drawing die

Conical drawing die

- Shape of the bell causes hydrostatic pressure to increase and promotes the flow of lubricant into the die.
- The approach angle – where the actual reduction in diameter occurs, giving the half die angle α.
- The bearing region produces a frictional drag on the wire and also remove surface damage due to die wear, without changing dimensions.
- The back relief allows the metal to expand slightly as the wire leaves the die and also minimises abrasion if the drawing stops or the die is out of alignment.



Drawing

Sheet metal forming to make cup-shaped, box-shaped, or other complex-curved, hollow-shaped parts

Products: beverage cans, ammunition shells, automobile body panels

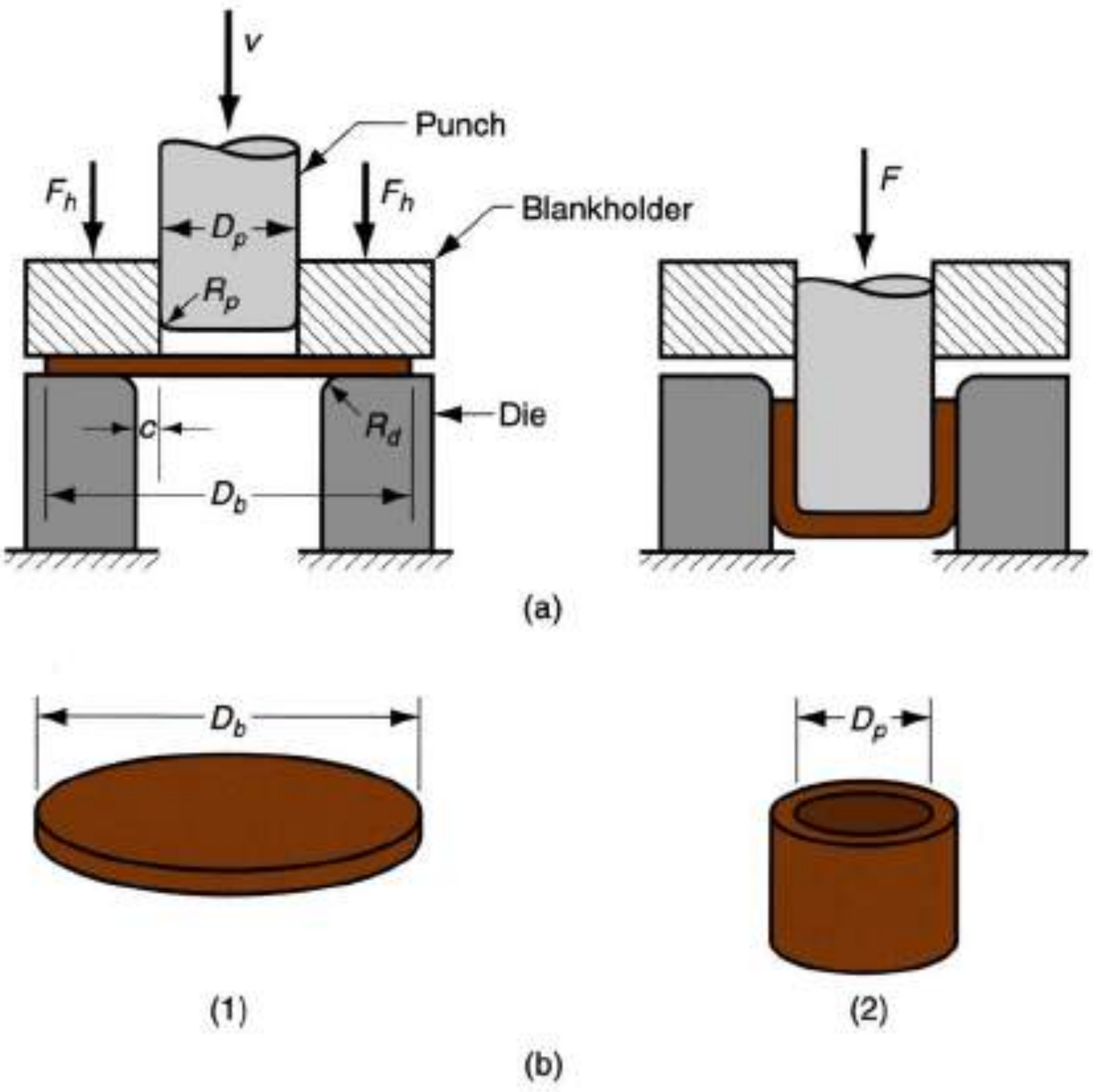


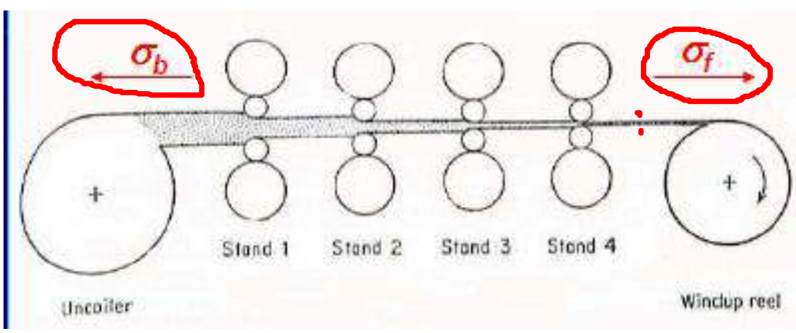
Fig. Rolling mills

the next pair of roll. This improves the productivity. Rolling power is directly proportional to roll diameter. Smaller dia rolls can therefore reduce power input. Strength of small diameter rolls are poor. Therefore, rolls may bend. As a result, largerdia backup rolls are used for supporting the smaller rolls. Four high rolling mill is one such mill. Thin sections can be rolled using smaller diameter rolls. Cluster mill and Sendzimir mill are used for rolling thin strips of high strength materials and foils [0.0025 mm thick]. The work roll in these mills may be as small as 6 mm diameter – made of tungsten carbide. Several rolling mills arranged in succession so as to increase productivity is called rolling stand. In such arrangement, anuncoiler and windup reels are used. They help in exerting back tension and front tension.

types of rolling processes:-

1. Continuous rolling

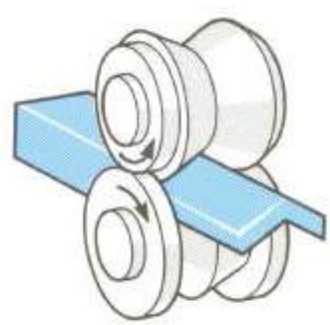
- Use a series of rolling mill and each set is called a stand.
- The strip will be moving at different velocities at each stage in the mill



The speed of each set of rolls is synchronised so that the input speed of each stand is equal to the output speed of preceding stand.

The uncoiler and windup reel not only feed the stock into the rolls and coiling up the final product but also provide back tension and front tension to the strip.

Shaped rolling or section rolling:-



• A special type of cold rolling in which flat slap is progressively bent into complex shapes by passing it through a series of driven rolls.

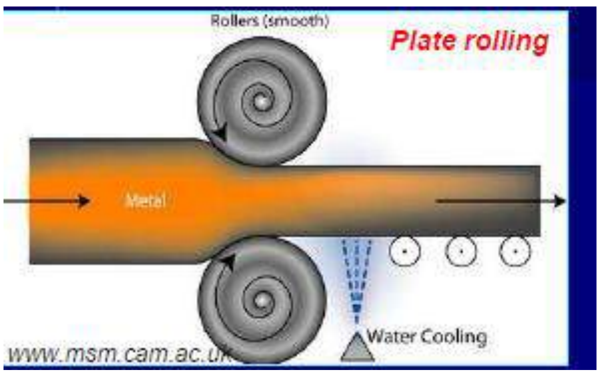
• No appreciable change in the thickness of the metal during this process.

• Suitable for producing moulded sections such as irregular shaped channels and trim.

Hot-rolling

• The first hot-working operation for most steel products is done on the primary roughing mill (blooming, slabbing or cogging mills).

• These mills are normally two-high reversing mills with 0.6-1.4 m diameter rolls (designated by size).



• The objective is to breakdown the cast ingot into blooms or slabs for subsequent finishing into bars, plate or sheet.

• In hot-rolling steel, the slabs are heated initially at 1100 -1300 °C. The temperature in the last finishing stand varies from 700 - 900 °C, but should be above the upper critical temperature to produce uniform equiaxed ferrite grains.

Cold-rolling:-

• Cold rolling is carried out under recrystallisation temperature and introduces work hardening.

. The starting material for cold-rolled steel sheet is pickled hot-rolled breakdown coil from the continuous hot-strip mill.

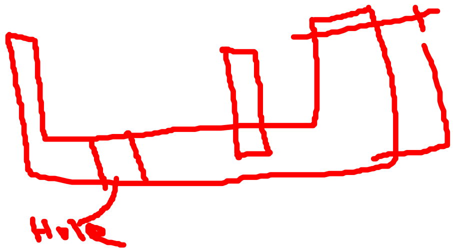
• Cold rolling provide products with superior surface finish (due to low temperature - no oxide scales)

• Better dimensional tolerances compared with hot-rolled products due to less thermal expansion.

- Cold-rolled nonferrous sheet may be produced from hot-rolled strip, or in the case of certain copper alloys it is cold-rolled directly from the cast state.

Advantages of die casting:

- Excellent dimensional accuracy (dependent on casting material, but typically 0.1 mm for the first 2.5 cm (0.005 inch for the first inch) and 0.02 mm for each additional centimeter (0.002 inch for each additional inch).
- Smooth cast surfaces (Ra 1–2.5 micrometres or 0.04–0.10 thou rms).
- Thinner walls can be cast as compared to sand and permanent mold casting (approximately 0.75 mm or 0.030 in).
- Inserts can be cast-in (such as threaded inserts, heating elements, and high strength bearing surfaces).
- Reduces or eliminates secondary machining operations.
- Rapid production rates.
- Casting tensile strength as high as 415 megapascals (60 ksi).
- Casting of low fluidity metals.

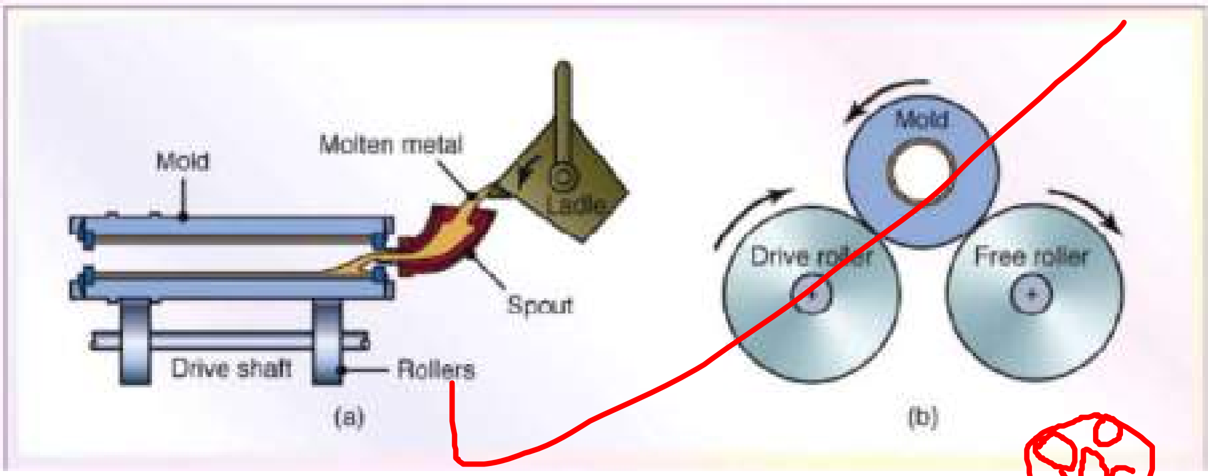


Centrifugal Casting:

❖ As the name implies, the centrifugal-casting process utilizes the inertial forces caused by rotation to distribute the molten metal into the mold cavities.

❖ First suggested in the early 1800s.

❖ There are three types of centrifugal casting: True centrifugal, semi-centrifugal, and centrifuging casting.



A. True centrifugal Casting

- In true centrifugal casting, hollow cylindrical parts (such as pipes, gun barrels, bushings, bearing rings, and streetlamp posts) are produced.
- In this technique the molten metal is poured into a rotating mold. The axis of rotation is usually horizontal but can be vertical for short work-pieces.
- Molds are made of steel, iron, or graphite, and may be coated with a refractory lining to increase mold life.
- The mold surfaces can be shaped so that pipes with various external designs can be cast.
- Cylindrical parts ranging from 13 mm to 3 m in diameter and 16 m long can be cast centrifugally, with wall thicknesses ranging from 6 mm to 125 mm.
- Castings with good quality, dimensional accuracy, and external surface detail are obtained by this process.

METAL FORMING: -

Metal forming includes a large group of manufacturing processes in which plastic deformation is used to change the shape of metal work pieces. Deformation results from these of a tool, usually called a die in metal forming, which applies stresses that exceed the yield strength of the metal. The metal therefore deforms to take a shape determined by the geometry of the die. Metal forming dominates the class of shaping operations.

Metal Forming:-

Metal forming processes can be classified into two basic categories: bulk deformation processes and sheet metalworking processes.. Each category includes several major classes of shaping operations as indicated in Figure (2)

Large group of manufacturing processes in which plastic deformation is used to change the shape of metal work pieces

- The tool, usually called a die, applies stresses that exceed yield strength of metal
- The metal takes a shape determined by the geometry of the die

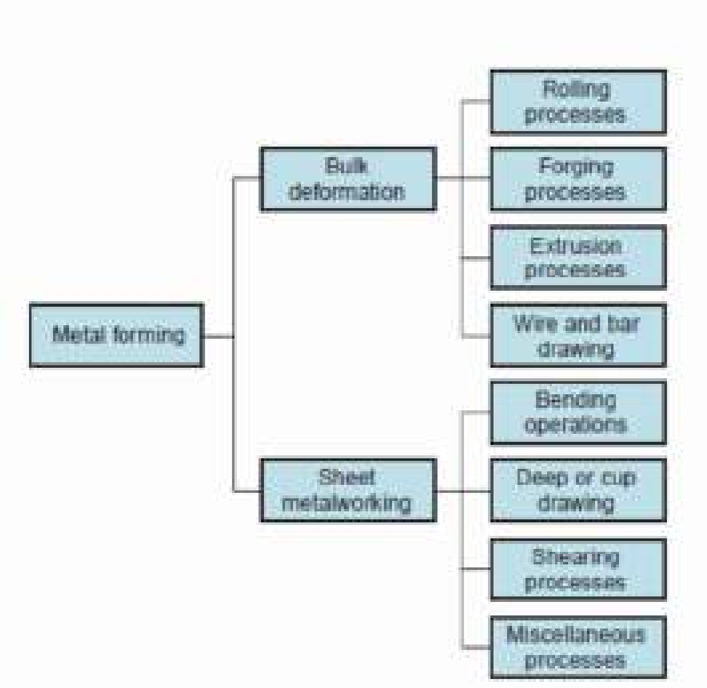
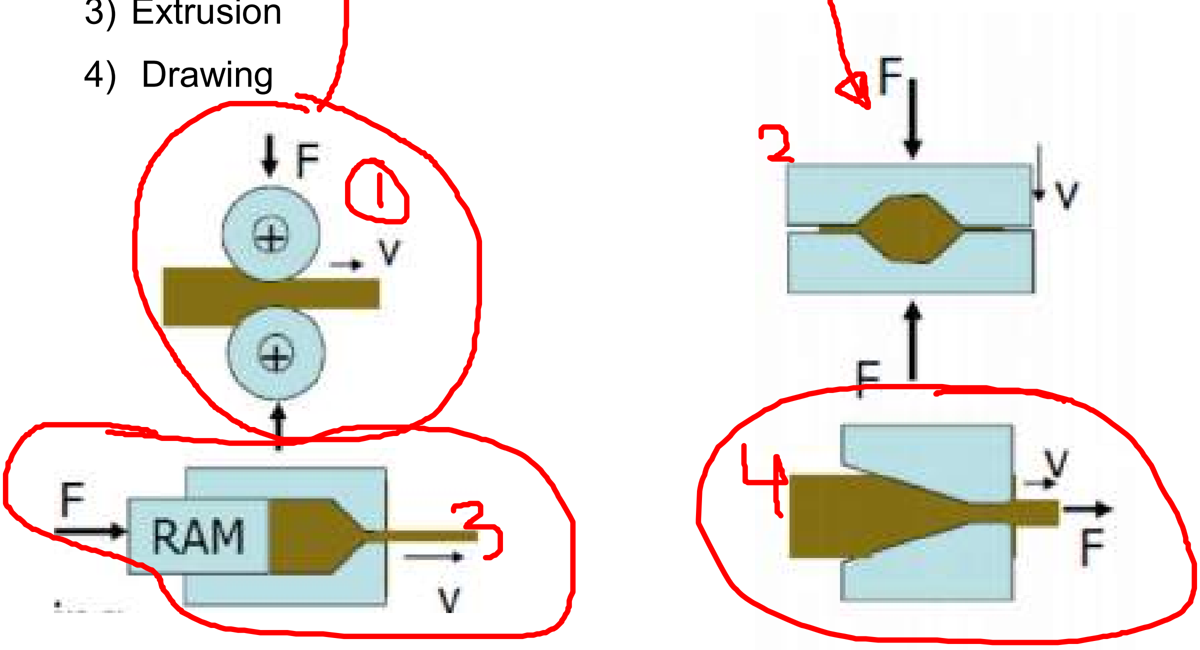


FIGURE Classification of metal forming operations

Classification of Metal forming

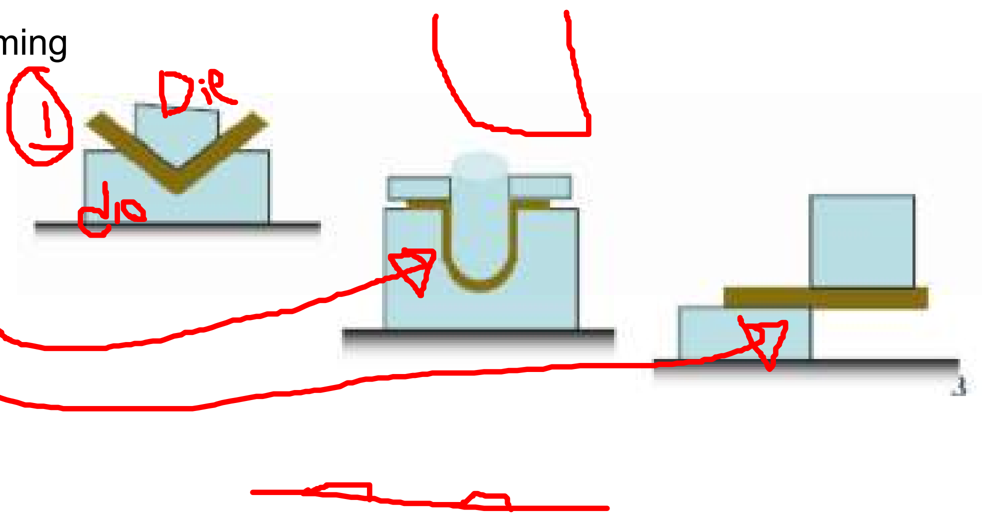
1- Bulk Deformation Process

1) Rolling
2) **Forging**
3) Extrusion
4) Drawing



2- Sheet metal forming

1) Bending
2) Drawing
3) Shearing
4) Stamping

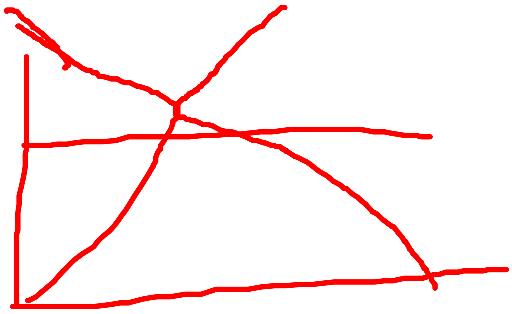


Temperature in Metal Forming:-

•Any deformation operation can be accomplished with lower forces and power at elevated temperature

•Three temperature ranges in metal forming:

1- Cold working
2- Warm working
3- Hot working



Cold Working

Cold working (also known as cold forming) is metal forming performed at room temperature or slightly above. Significant advantages of cold forming compared

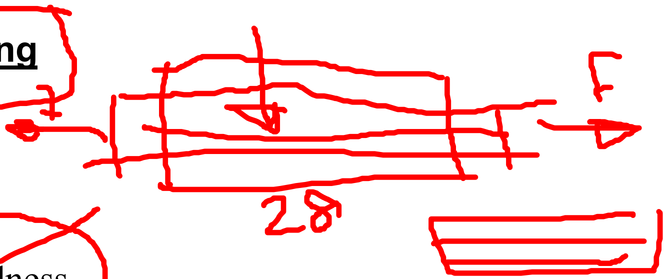
- Performed at room temperature or slightly above

•Many cold forming processes are important mass production operations

•Minimum or no machining usually required

- These operations are near net shape or net shape processes

Advantages of Cold Forming vs. Hot Working



•Better accuracy, closer tolerances

•Better surface finish

•Strain hardening increases strength and hardness

•Grain flow during deformation can cause desirable directional properties in product

•No heating of work required

Disadvantages of Cold Forming

•Higher forces and power required

•Surfaces of starting workpiece must be free of scale and dirt

•Ductility and strain hardening limit the amount of forming that can be done

A- In some operations, metal must be annealed to allow further deformation

B- In other cases, metal is simply not ductile enough to be cold worked

Warm Working

Performed at temperatures above room temperature but below recrystallization temperature

•Dividing line between cold working and warm working often expressed in terms of melting point:

- 0.3Tm, where Tm = melting point (absolute temperature) for metal

Advantages of Warm Working

•Lower forces and power than in cold working

•More intricate work geometries possible

•Need for annealing may be reduced or eliminated

Hot Working

•Deformation at temperatures above recrystallization temperature

•Recrystallization temperature = about one-half of melting point on absolute scale

A- In practice, hot working usually performed somewhat above 0.5Tm

B- Metal continues to soften as temperature increases above 0.5Tm, enhancing advantage of hot working above this level .

Why Hot Working

Capability for substantial plastic deformation of the metal - far more than possible with cold working or warm working

•Why?

1- Strength coefficient is substantially less than at room temperature

2- Strain hardening exponent is zero (theoretically)

3- Ductility is significantly increased

Advantages of Hot Working vs. Cold Working

1- Workpart shape can be significantly altered

2- Lower forces and power required

3- Metals that usually fracture in cold working can be hot formed

4- Strength properties of product are generally isotropic

5- No strengthening of part occurs from work hardening

- Advantageous in cases when part is to be subsequently processed by cold forming

Disadvantages of Hot Working

•Lower dimensional accuracy

•Higher total energy required (due to the thermal energy to heat the workpiece)

•Work surface oxidation (scale), poorer surface finish

•Shorter tool life

- Safety hazards to workers due to hot molten metals
- Environmental problems

Applications

(*i*) This method is suitable for small and medium sized casting such as carburetor bodies, oil pump bodies, connecting rods, pistons etc.

(*ii*) It is widely suitable for non-ferrous casting.

Casing types: -

There are many types of casting divided by equipment or die materials used in it and the most important of these are:

1. Sand Casting
2. Die Casting
3. Centrifugal Casting

Casting is usually performed in a foundry. The Foundry in the factory equipped for

- making molds
- melting and handling molten metal
- performing the casting process
- cleaning the finished casting

Workers who perform casting are called foundry men

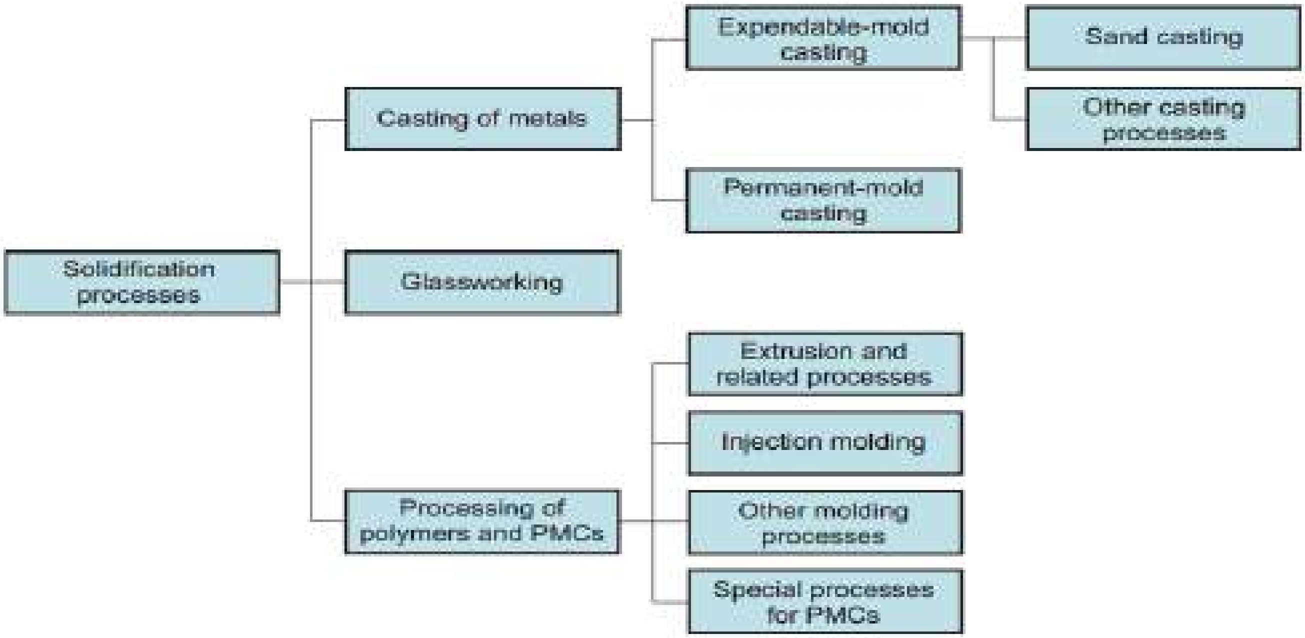
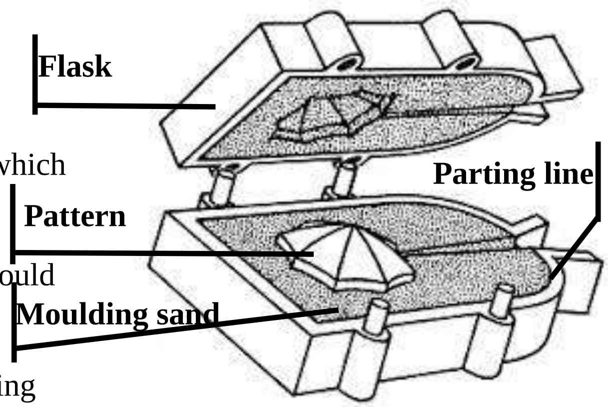


FIGURE Classification of solidification processes.

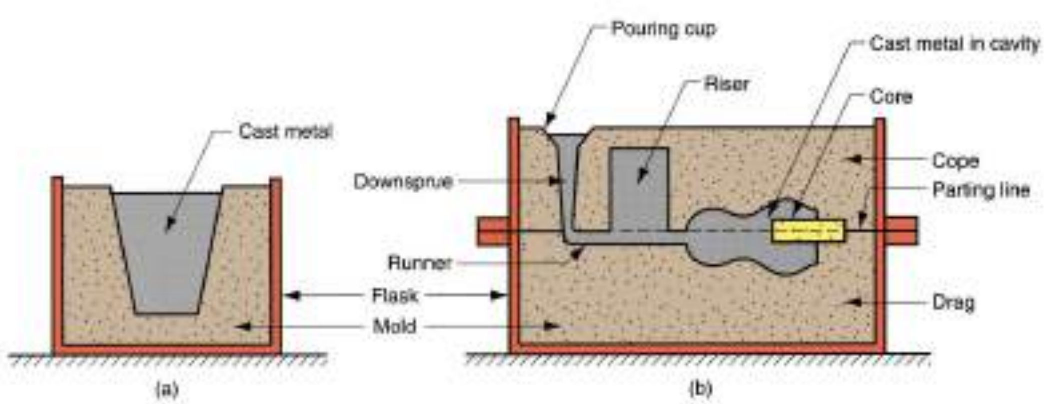


Flask: A metal or wood frame, without fixed top or bottom, in which the mould is formed. Flask used in three piece moulding.

1-Pattern: It is the replica of the final object to be made. The mould cavity is made with the help of pattern.

2-**Parting line**: This is the dividing line between the two moulding flasks that makes up the mould.

3-Moulding sand: Sand, which binds strongly without losing its permeability to air or gases. It is a mixture of silica sand, clay, and moisture in appropriate proportions.



Facing sand: The small amount of carbonaceous material sprinkled on the inner surface of the mould cavity to give a better surface finish to the castings

Core: A separate part of the mould, made of sand and generally baked, which is used to create openings and various shaped cavities in the castings.

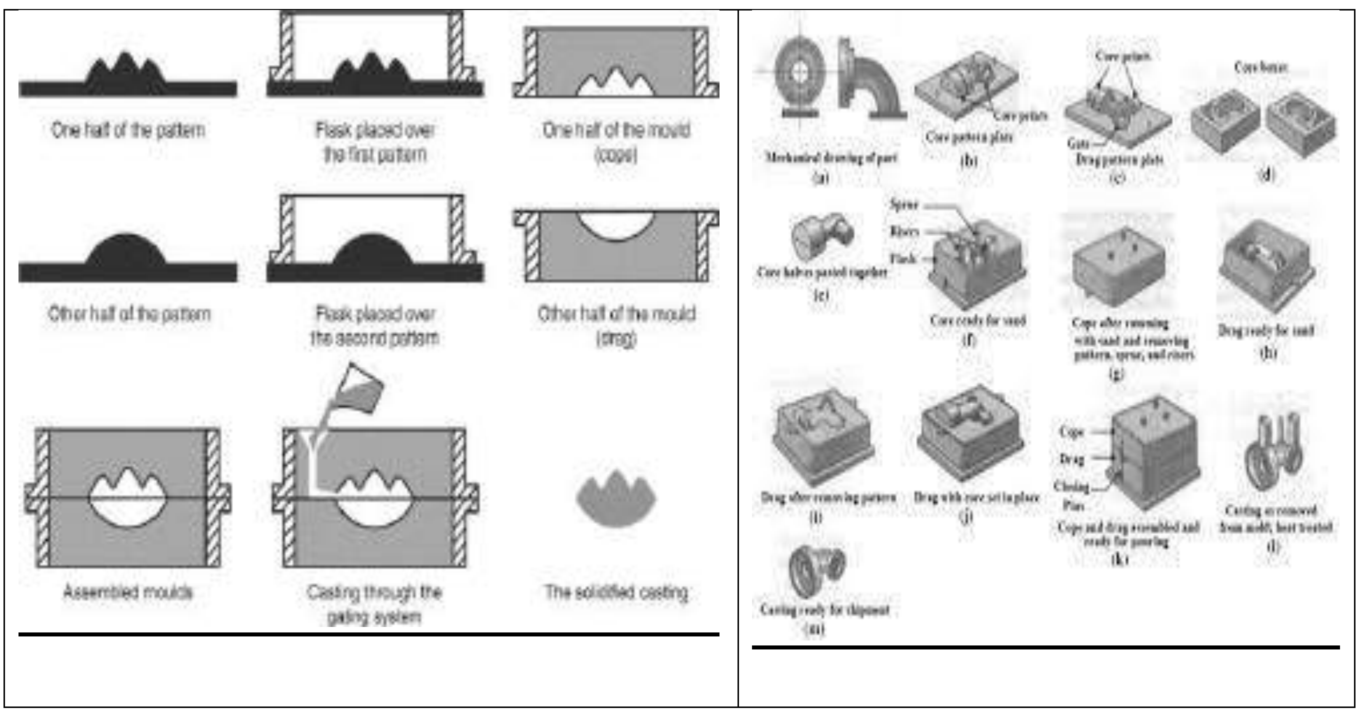
Pouring basin: A small funnel shaped cavity at the top of the mould into which the molten metal is poured.

Sprue: The passage through which the molten metal, from the pouring basin, reaches the mould cavity. In many cases it controls the flow of metal into the mould.

Runner: The channel through which the molten metal is carried from the sprue to the gate.

Riser: A column of molten metal placed in the mould to feed the castings as it shrinks and solidifies. Also known as “feed head”.

Vent: Small opening in the mould to facilitate escape of air and gases.



Steps in making sand castings

The six basic steps in making sand castings are,

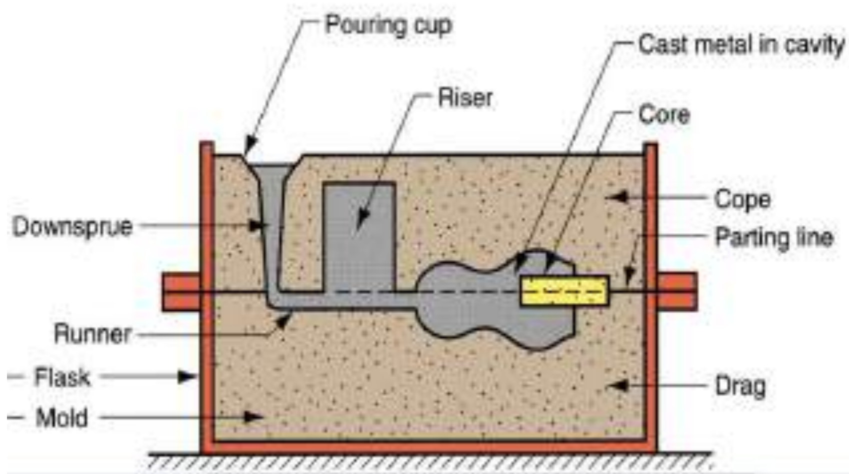
(i) Pattern making,

(ii) Core making,

(iii) the Gating System

(iv) Melting and pouring,

(v) Cleaning



Step-1. Pattern making

Pattern: Replica of the part to be cast and is used to prepare the mould cavity. Made of wood or metal , plastic, or other material and has the shape of the part to be cast.

*The cavity is formed by packing sand around the pattern, about half each in the cope and drag, so that when the pattern is removed, the remaining void has the desired shape of the cast part.

*The pattern is usually made oversized to allow for shrinkage of the metal as it solidifies and cools. The sand for the mold is moist and contains a binder to maintain its shape.

Step-2. Core making

Cores are placed into a mould cavity to form the interior surfaces of castings. Thus the void space is filled with molten metal and eventually becomes the casting.

Step-3. Set Up the Gating System

Most casting processes involve the use of a gating system, and sand casting is no exception. Consisting of a pouring cup and tunnels or "gates" to the mold, it's used to funnel the molten mold into the mold cavity. The mould cavity contains the liquid metal and it acts as a negative of the desired product.

Step-4. Melting and Pouring The preparation of molten metal for casting is referred to simply as melting. The molten metal is transferred to the pouring area where the moulds are filled.

Step-5. Cleaning : involves removal of sand, scale, and excess metal from the casting. Burned-on sand and scale are removed to improved the surface appearance of the casting. Excess metal, in the form of fins, wires, parting line fins, and gates, is removed. Inspection of the casting for defects and general quality is performed.

Making a simple sand mould

1)The drag flask is placed on the board

2)Dry facing sand is sprinkled over the board

3)Drag half of the pattern is located on the mould board. Dry facing sand will provide a non-sticky layer.

4)Molding sand is then poured in to cover the pattern with the fingers and then the drag is filled completely

5)Sand is then tightly packed in the drag by means of hand rammers. Peen hammers (used first close to drag pattern) and butt hammers (used for surface ramming) are used.

6) The ramming must be proper i.e. it must neither be too hard or soft. Too soft ramming will generate weak mould and imprint of the pattern will not be good. Too hard ramming will not allow gases/air to escape and hence bubbles are created in casting resulting in defects called 'blows'. Moreover, the making of runners and gates will be difficult.

7) After the ramming is finished, the excess sand is leveled/removed with a straight bar known as strike rod.

https://www.youtube.com/watch?v=GIy-vl5oSvo&t=63s

Solidification of Metals:-

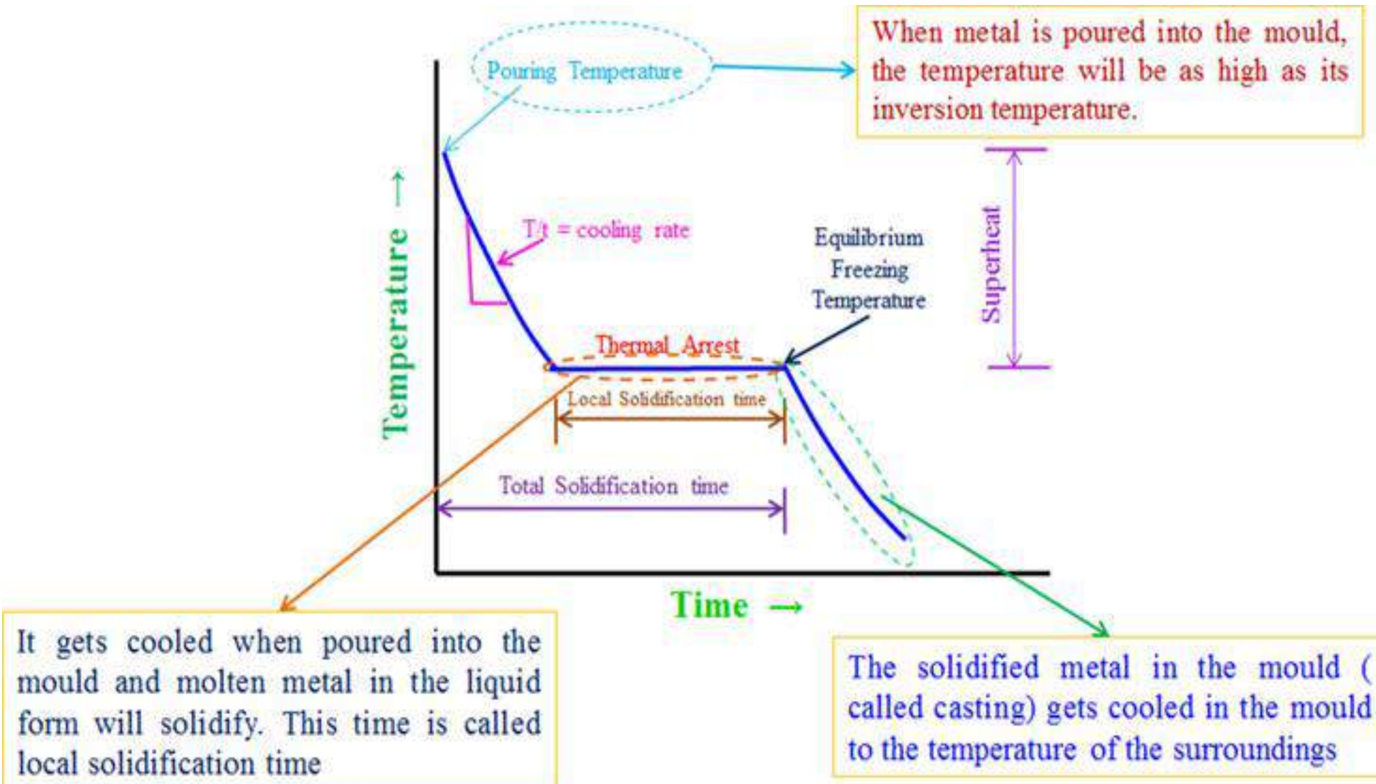
It is the transformation of molten metal back into solid state

- Solidification differs depending on whether the metal is
  - A pure element or
  - An alloy
  - A Eutectic alloy
- Ref cooling curve:

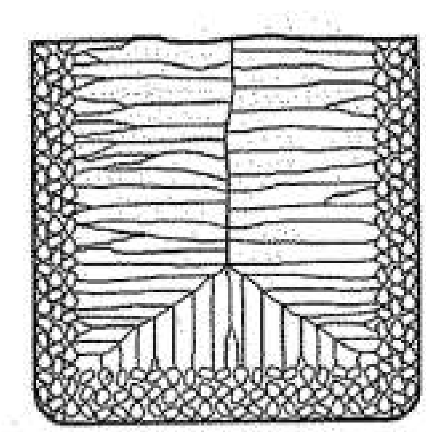
- Pure metal solidifies at a constant temperature equal to its freezing point (same as melting point).
- Local freezing time= Time from freezing begins and completed
- Total freezing time= Time from pouring to freezing completed

- After freezing is completed, the solid continues to cool at a rate indicated by downward slope of curve

•



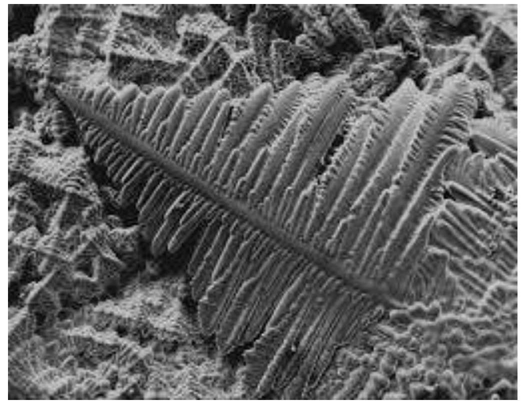
- Because of the chilling action of the mold wall, a thin skin of solid metal is initially formed at interface immediately after pouring.
- The skin formed initially has equi-axed, fine grained and randomly oriented structure. This is because of rapid cooling.
- As freezing proceeds, the grains grow inwardly, away from heat flow direction, as needles or spine of solid metal.



On further growth of spine, lateral branches are formed, and as these branches grow further branches are formed at right angle to the first branches. This type of growth is called dendritic growth.

The dendritic grains are coarse, columnar and aligned towards the center of casting

- Most alloys freeze at range of temperature rather than at a single temperature.
- Freezing begins from liquid us temperature and completes at solidus temperature.



- The cooling begins in the same manner as that in pure metals; a thin skin is formed at the interface of mold and makes shell as freezing proceeds.
- The dendrites begin to form with freezing. However, due to large temperature spread between solidus and liquidus, the earlier portion of dendritic grains extract higher % of elements from liquid solution than the portion of grain formed later.
- As a result, the molten metal in the center of mold cavity depletes from the elements and hence forms a different structure (see Fig).

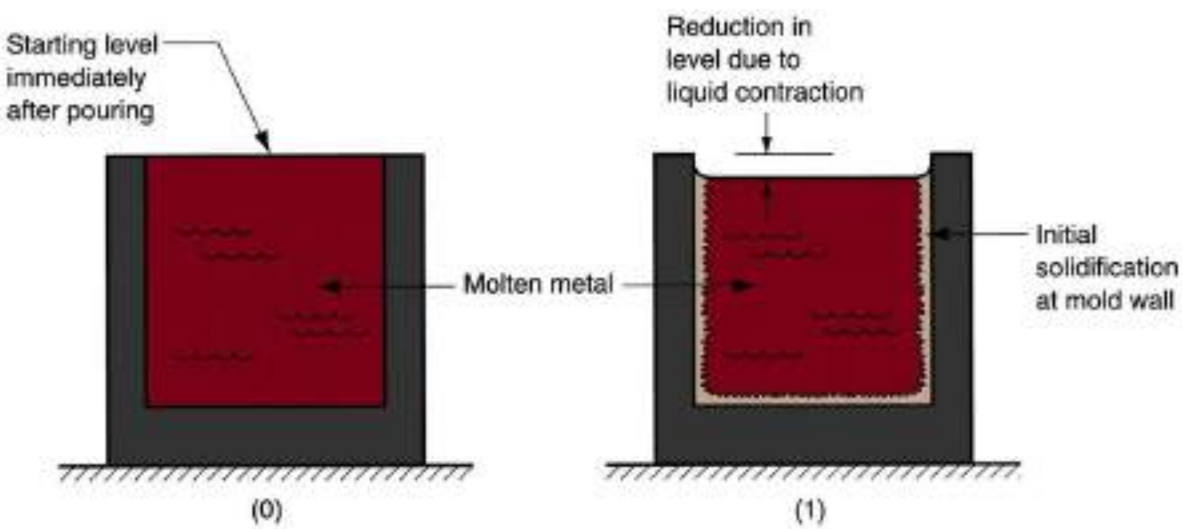
Shrinkage in Solidification and Cooling

Shrinkage occurs in 3 steps:

a. while cooling of metal in liquid form (liquid contraction);

b. during phase transformation from liquid to solid (solidification shrinkage);

c. while solidified metal is cooled down to room temperature (solid thermal contraction).



(2) reduction in height and formation of shrinkage cavity caused by solidification shrinkage; (3) further reduction in height and diameter due to thermal contraction during cooling of solid metal (dimensional reductions are exaggerated for clarity).

Why cavity forms at top, why not at bottom?

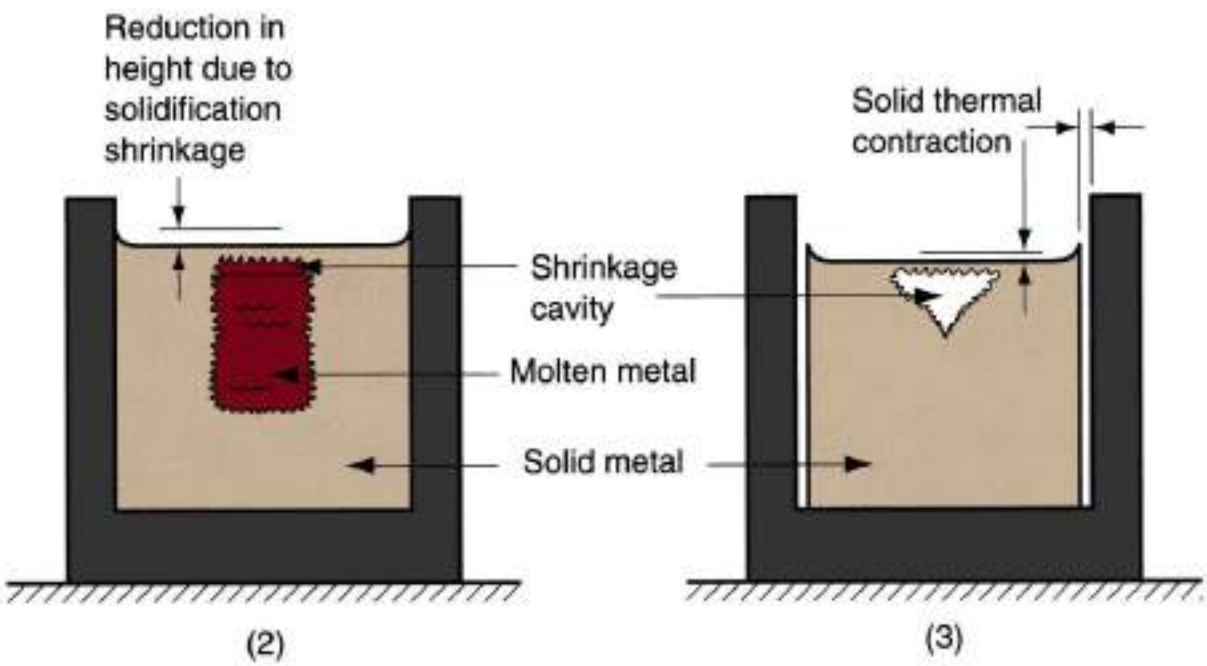
Solidification Shrinkage (Liquid –Solid transformation)

- Occurs in nearly all metals because the solid phase has a higher density than the liquid phase
- Thus, solidification causes a reduction in volume per unit mass of metal
- Exception: cast iron with high C content
    - Graphitization during final stages of freezing causes expansion that counteracts volumetric decrease associated with phase change

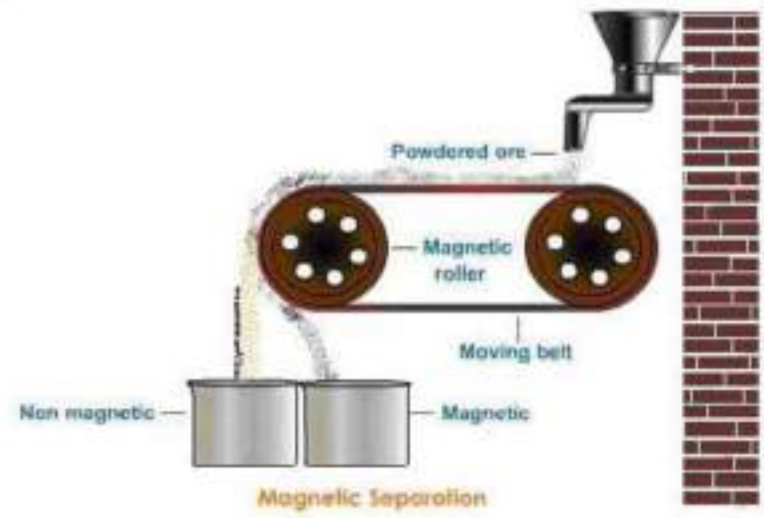
Why solidification shrinkage is negligible in Cast Irons??

Shrinkage Allowance

- Patternmakers account for solidification shrinkage and thermal contraction by making mold cavity oversized
- Amount by which mold is made larger relative to final casting size is called *pattern shrinkage allowance*
- Casting dimensions are expressed linearly, so allowances are applied accordingly.



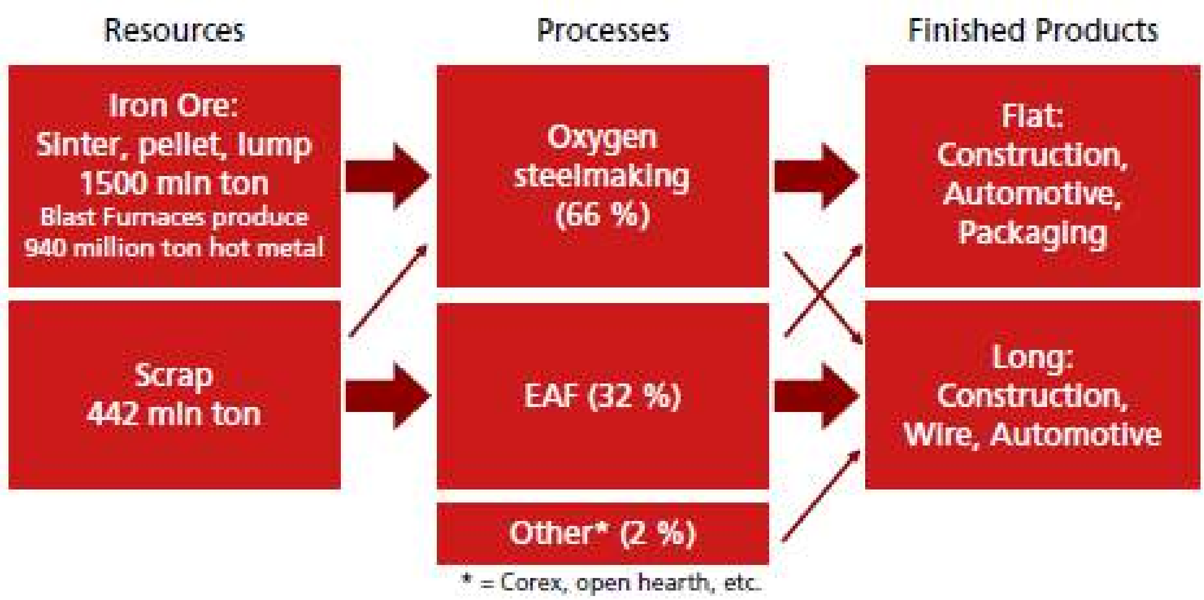
influence of gravity. The magnetic ore and gangue thus form two separate heaps. Following figure shows the magnetic separation method



B))PELLETIZATION: Iron ore pellets are spheres of typically 6–16 mm to be used as raw material for blast furnaces. They typically contain 67%-72% Fe and various additional material adjusting the chemical composition and the metallurgic properties of the pellets.[1] Typically limestone, dolostone and olivine is added and Bentonite is used as binder.

- Three thermodynamically stable species of Iron oxides:
  - Hematite: Fe_2O_3
  - Magnetite: Fe_3O_4

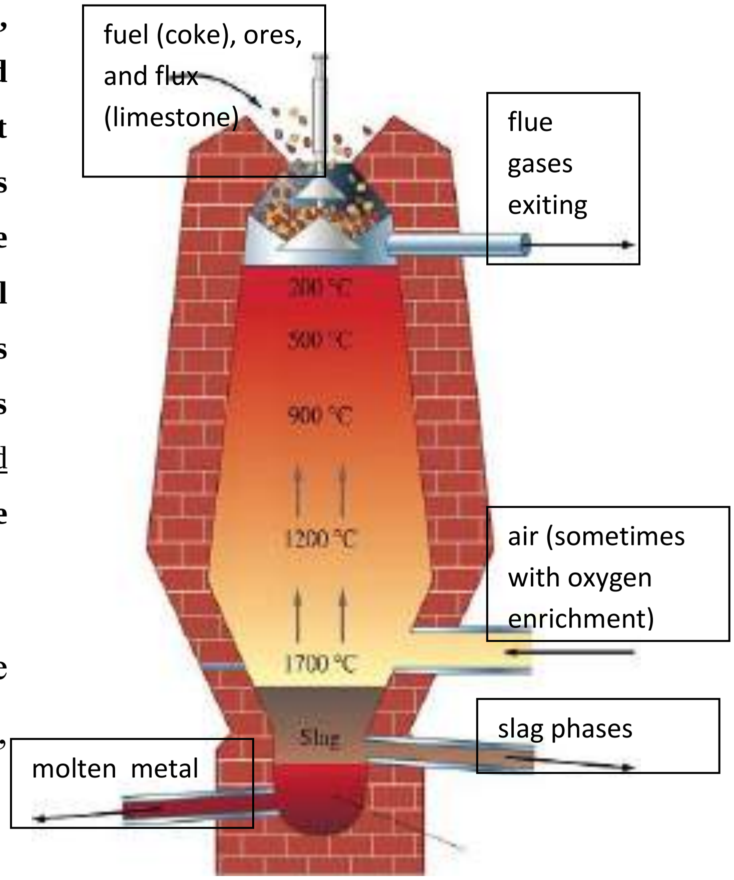
Two different process routes are available for the production of steel products, namely **the blast furnace** with oxygen steelmaking and **the electric arc steelmaking route**. The routes differ with respect to the type of products that can be made, as well as the raw materials used. The blast furnace–oxygen steelmaking route mainly produces flat products, while electric arc steelmaking is more focused on long products. The former uses coke and coal as the main reductant sources and sinter, pellets and lump ore as the iron–bearing component, while the latter uses electric energy to melt scrap. The current trend is for electric arc furnaces to be capable of also producing flat products. Nevertheless, the blast furnace–oxygen steelmaking route remains the primary source for worldwide steel production, as shown in Figure



Blast furnace

A blast furnace **is a type of <u>metallurgical</u> <u>furnace</u> used for <u>smelting</u> to produce industrial metals and its alloys, generally <u>iron</u>,**

In a blast furnace fuel (coke)**, ores, and** flux (limestone) **are continuously supplied through the top of the furnace, while a hot blast of** air (sometimes with oxygen enrichment) **is blown into the** lower section **of the furnace through a series of pipes. so that the chemical reactions take place throughout the furnace as the material falls downward. The end products are usually** molten metal and slag phases tapped from the bottom**, and** flue gases exiting **from the top of the furnace.**



- Iron ore, limestone($CaCO_3$) and coke are delivered to the top of the blast furnace, where the temperature is around 800C.

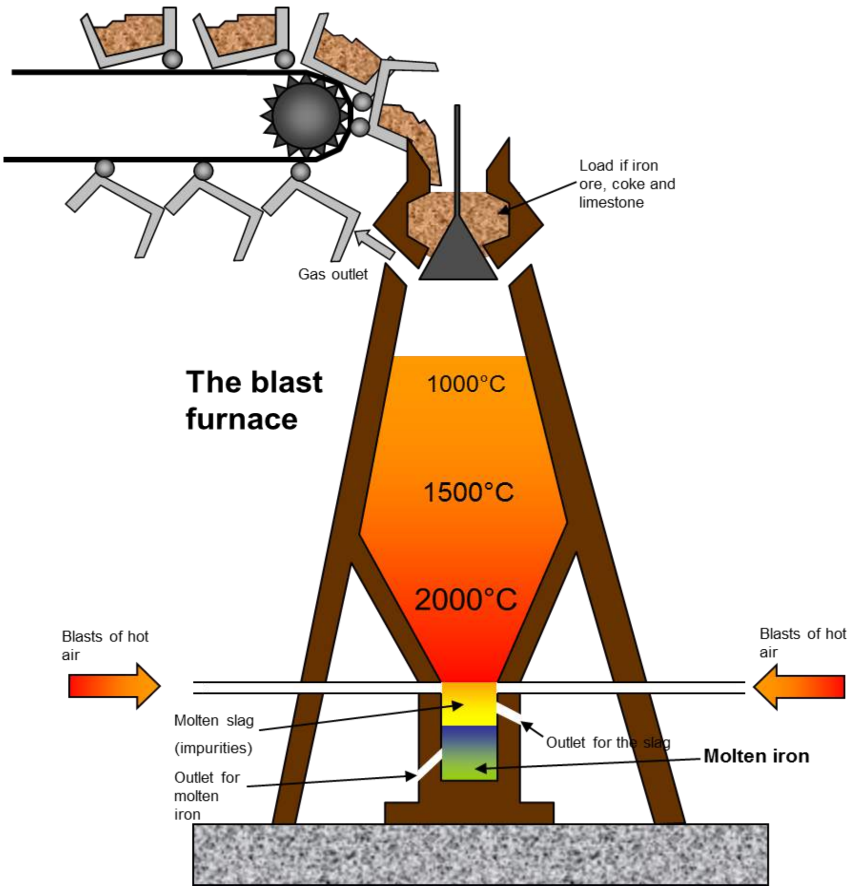
- The lime stone burns at 800C yielding calcium oxide(CaO) and Carbon Dioxide(CO2).

$$CaCO_3 \rightarrow CaO + CO_2$$

- The Calcium oxide causes impurities which are present with the ore to fall as a precipitate near to the bottom producing a layer of “slag”.

Extracting iron from its ore

Chemical reduction with carbon



1. Raw materials (iron ore, coke and limestone) are added at the top of the furnace.

2. Blasts of hot air (which give the furnace its name) are blown in near the bottom of the furnace.

3. Oxygen in the blasts of air reacts with coke (carbon) to form carbon monoxide.

$$2C + O_2 \rightarrow 2CO$$

This reaction is very exothermic and the temperature in the furnace reached 2000°C.

4. As the carbon monoxide rises up the furnace, it reacts with the iron ore (iron(III) oxide to form iron.

$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

5. Molten iron runs to the bottom of the furnace. It is tapped off from time to time.

6. The molten iron is used to make steel or poured into moulds to solidify. The large chunks of iron formed are called 'pigs' so this metal is called 'pig iron'.

- Each Carbon monoxide molecule is capable of binding a single oxygen so 3 are used to completely remove all oxygen from the iron oxide.
- $Fe_2O_3 + 3\ CO \rightarrow 2Fe(s) + 3\ CO_2$
- The molten iron sinks to the bottom lowest level of the furnace, where it can be tapped off.
- The iron produced by this process is called pig iron and is 95% pure
- Production of iron from it's ore uses Carbon monoxide to reduce Iron oxide to iron atoms.

1.Lime burns

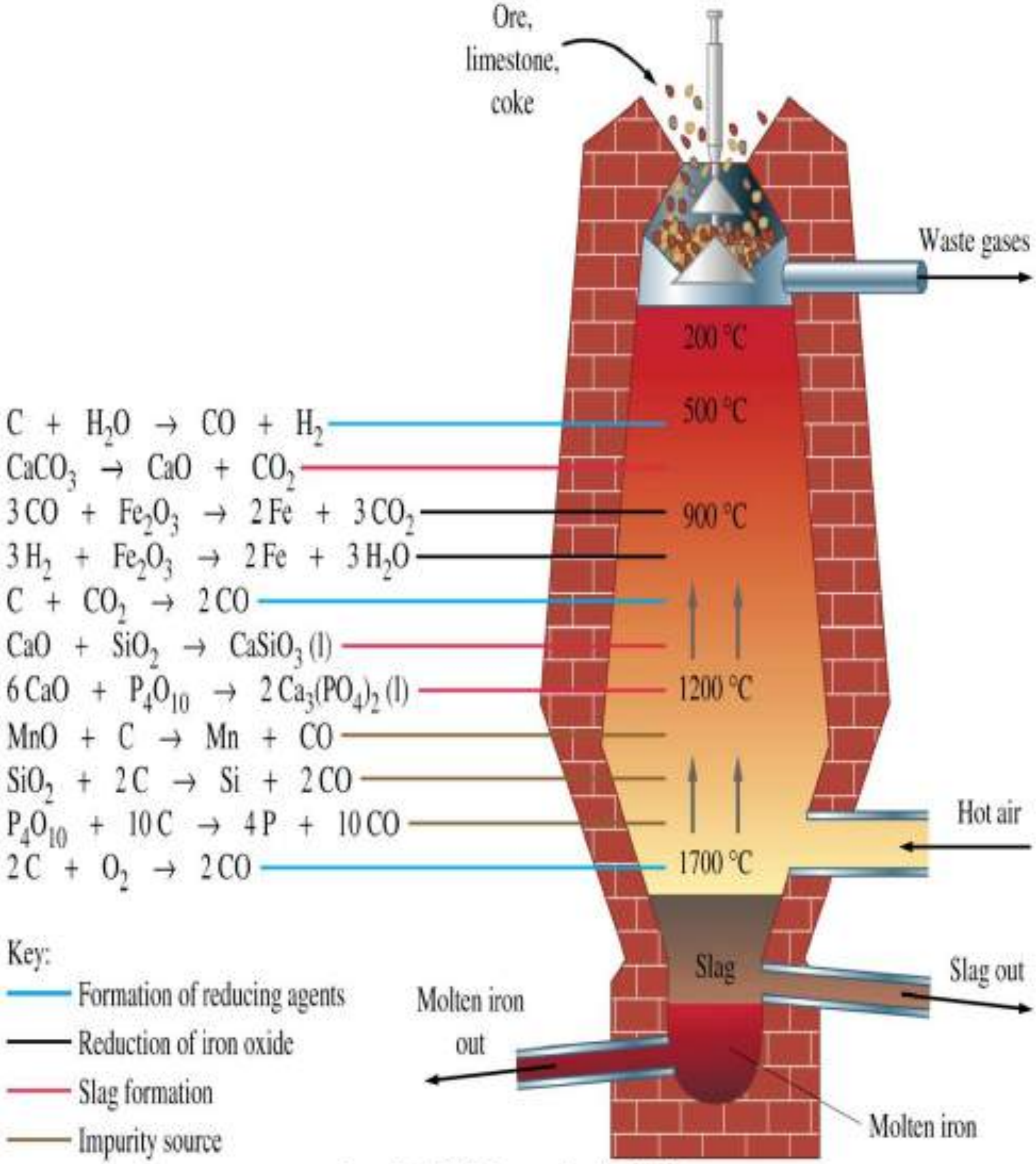
$CaCO_3 \rightarrow CaO + CO_2$

2. CO2 reduced by coke to CO

$CO_2 + C \rightarrow 2\ CO$

3. Iron oxide reduced by CO

$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$


Ore, limestone, coke
Waste gases
200 °C
500 °C
900 °C
1200 °C
1700 °C
Hot air
Slag
Slag out
Molten iron out
Molten iron
$C + H_2O \rightarrow CO + H_2$
$CaCO_3 \rightarrow CaO + CO_2$
$3CO + Fe_2O_3 \rightarrow 2Fe + 3CO_2$
$3H_2 + Fe_2O_3 \rightarrow 2Fe + 3H_2O$
$C + CO_2 \rightarrow 2CO$
$CaO + SiO_2 \rightarrow CaSiO_3(l)$
$6CaO + P_4O_{10} \rightarrow 2Ca_3(PO_4)_2(l)$
$MnO + C \rightarrow Mn + CO$
$SiO_2 + 2C \rightarrow Si + 2CO$
$P_4O_{10} + 10C \rightarrow 4P + 10CO$
$2C + O_2 \rightarrow 2CO$
Key:
Formation of reducing agents
Reduction of iron oxide
Slag formation
Impurity source

What is manufacturing?

Manufacturing is a blend of art, science, and economics with very broad social implications.

Three Pillars of Manufacturing

- Scientific Sense
- Engineering (Practical) Sense
- Economic Sense

Process: a series of actions that you take in order to achieve a result.

Goal: The course aims to impart the basic knowledge about the fundamental manufacturing techniques employed to convert a raw material into final product.

Why do you need to take this course?

- A knowledge of the basic manufacturing processes is essential for a successful engineer in today's global marketplace
- A company must produce products in an optimal way to compete in today's global marketplace

Types or steps of Manufacturing Processes

1- Extraction of metals and materials.
2- casting.
3- deformation.
4- machining.
5- welding and joining.
6- heat treatment.
7- surface finishing.

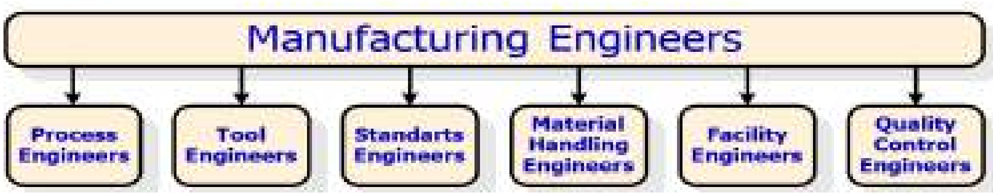
Automation

- Meaning: Automation (of *Greek* origin)
  Auto ⟶ Self
  Matos ⟶ Acting/moving
- Definition: Automation is a form of manufacturing in which production, movement, and inspection are performed by self-operating machine without human intervention. The skill of a human operator is essentially transfered to a specialized machine.

- Mechanization implies an operation being performed by a mechanical system (not by hand).
  - It is generally based on open-loop (no feedback) control strategy.
  - Ex: Use of a cam mechanism to move the cross-slide of a lathe.

Manufacturing Engineering

Application of science, engineering, technology, and economics to manufacture products of a quality, quantity, and cost competitiveness in the market place.



Manufacturing Processes

1. Primary Forming: Casting, powder metallurgy
2. Deforming: Metal forming processes (bulk and sheet forming)
3. Separating: Machining
   - Conventional machining (turning, milling, grinding, etc.)
   - Non-traditional machining (EDM, ECM, EBM, LBM, etc.)
4. Joining: Welding, brazing, riveting, etc.
5. Coating: Painting, electroplating, etc.
6. Changing Material Properties: Heat treatments.

MANUFACTURING DEFINED

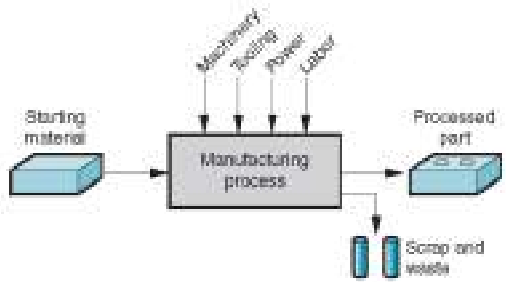
As a field of study in the modern context, manufacturing can be defined two ways, one technologic and the other economic. Technologically, manufacturing is the application of physical and chemical processes to alter the geometry, properties, and/or appearance of a given starting material to make parts or products; manufacturing also includes assembly of multiple parts to make products. The processes to accomplish manufacturing involve a combination of machinery, tools, power, and labor, as depicted in Figure 1.1(a).

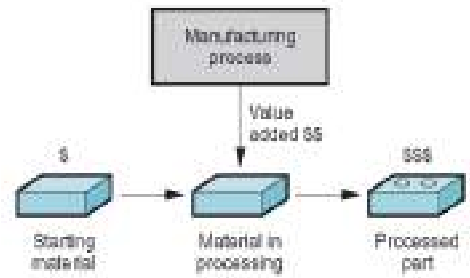
Manufacturing - Technological

- Application of physical and chemical processes to alter the geometry, properties, and/or appearance of a starting material to make parts or products

Manufacturing – Economic

Transformation of materials into items of greater value by one or more processing and/or assembly operations





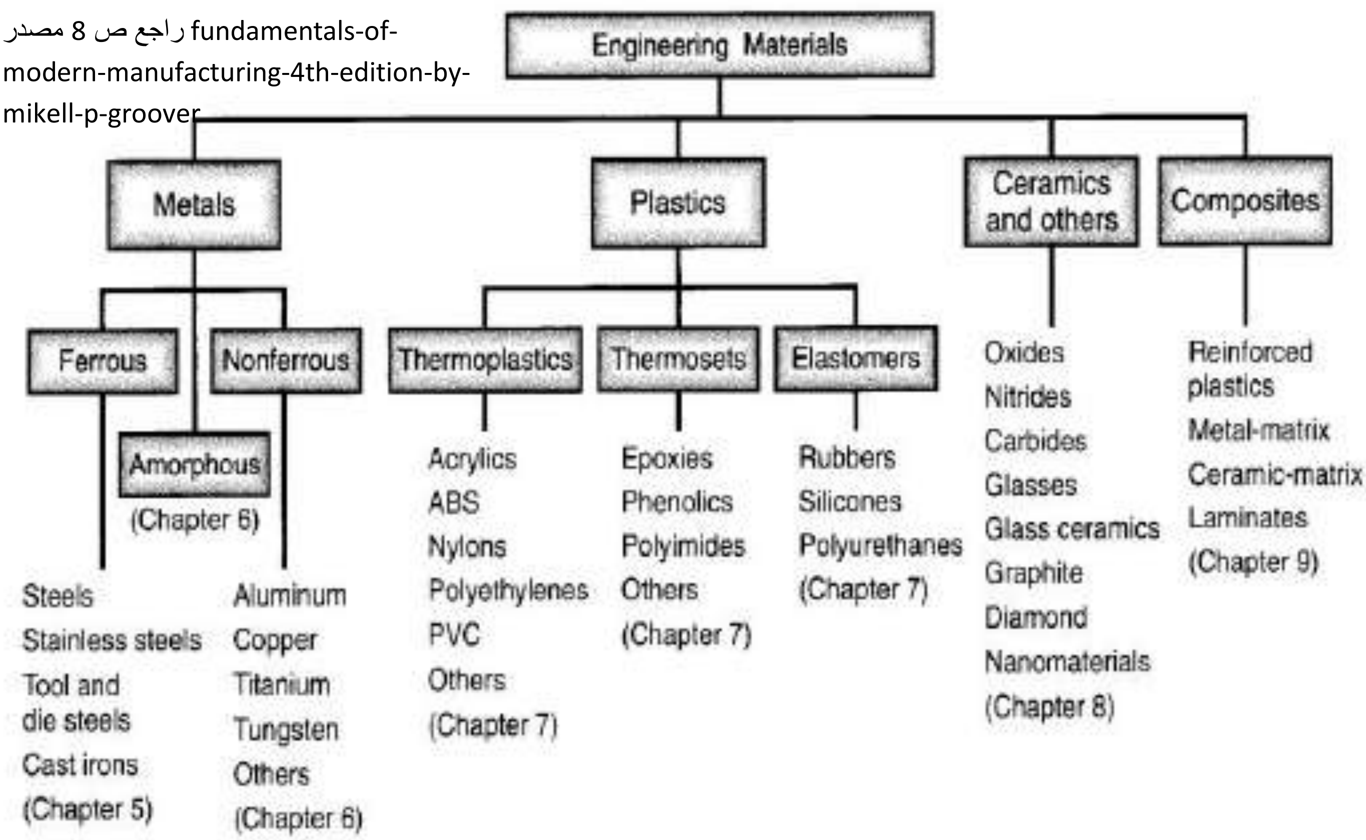
Economically, manufacturing is the transformation of materials into items of greater value by means of one or more processing and/or assembly operations, as depicted in Figure 1.1(b). The key point is that manufacturing adds value to the material by changing its shape or properties, or by combining it with other materials that have been similarly altered.

Most engineering materials can be classified into one of three basic categories:

(1) metals, (2) ceramics, and (3) polymers.

Their chemistries are different, their mechanical and physical properties are different, and these differences affect the manufacturing processes that can be used to produce products from them. In addition to the three basic categories, there are **(4) composites**—nonhomogeneous mixtures of the other three basic types rather than a unique category. The classification of the four groups is pictured in Figure below.

راجع ص 8 مصدر fundamentals-of-modern-manufacturing-4th-edition-by-mikell-p-groover



METALS

Metals used in manufacturing are usually alloys, Metals and alloys can be divided into two basic groups: (1) ferrous and (2) nonferrous.

Ferrous metals are based on iron; the group includes steel and cast iron. when alloyed with carbon, iron has more uses and greater commercial value than any other metal.

Alloys of iron and carbon form steel and cast iron. Steel can be defined as an iron–carbon alloy containing 0.02%to 2.11% carbon. Applications of steel include construction (bridges, I-beams, and nails), transportation (trucks, rails, and rolling stock for railroads), and consumer products automobiles and appliances). Cast iron is an alloy of iron and carbon (2% to 4%) used in casting (primarily sand casting).

CERAMICS

A ceramic is defined as a compound containing metallic (or semimetallic) and nonmetallic elements. Typical nonmetallic elements are oxygen, nitrogen, and carbon.

POLYMERS

A polymer is a compound formed of repeating structural units called mers, whose atoms share electrons to form very large molecules. COMPOSITES

COMPOSITES

they are mixtures of the other three types. A composite is a material consisting of two or more phases that are processed separately and then bonded together to achieve properties superior to those of its constituents. Properties of a composite depend on its components, Some composites combine high strength with light weight and are suited to applications such as aircraft components, car bodies.

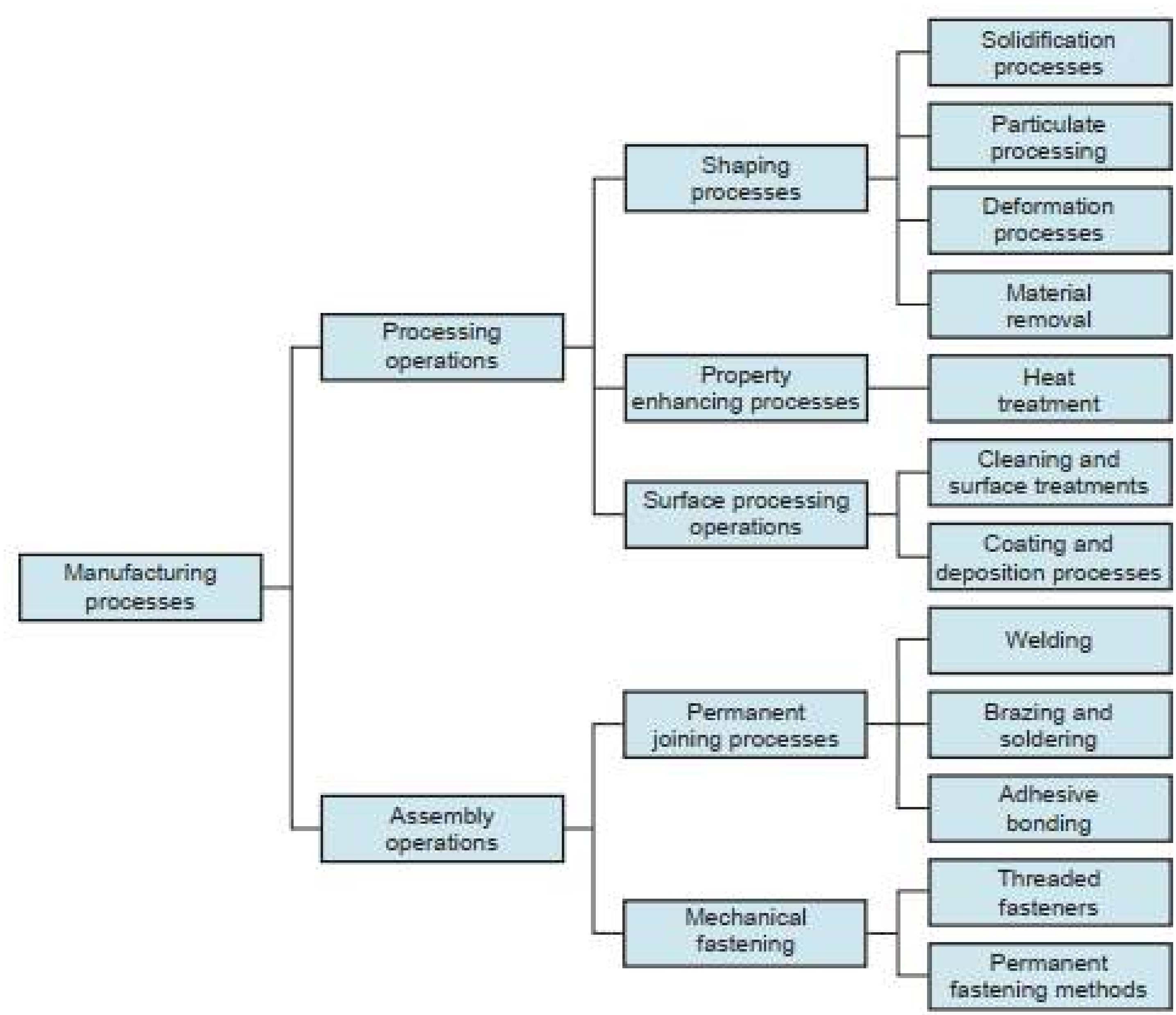
MANUFACTURING PROCESSES

A manufacturing process is a designed procedure that results in physical and/or chemical changes to a starting work material with the intention of increasing the value of that material.

A manufacturing process is usually carried out as a ***unit operation*** , which means that it is a single step in the sequence of steps required to transform the starting material into a final product.

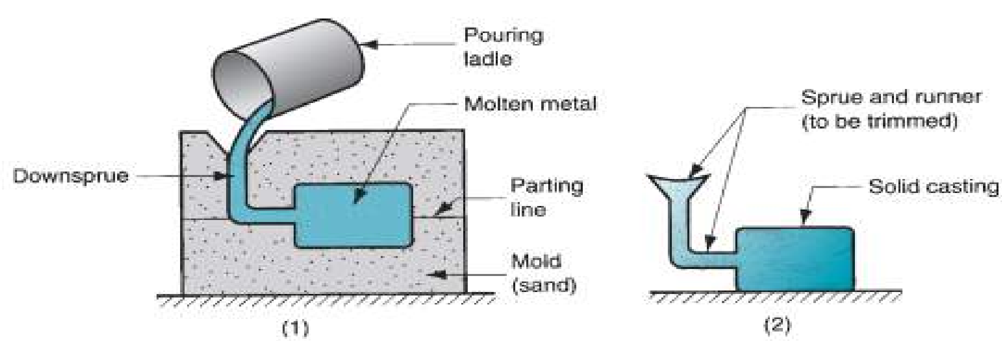
Manufacturing operations can be divided into two basic types: (1) processing operations and (2) assembly operations. It adds value by changing the geometry, properties, or appearance of the starting material. In general, processing operations are performed on discrete workparts, (e.g., painting a spot-welded car body).

An **assembly operation** joins two or more components to create a new entity, called an assembly, subassembly, to the joining process (e.g., a welded assembly is called a weldment). A classification of manufacturing processes is presented in Figure blew.

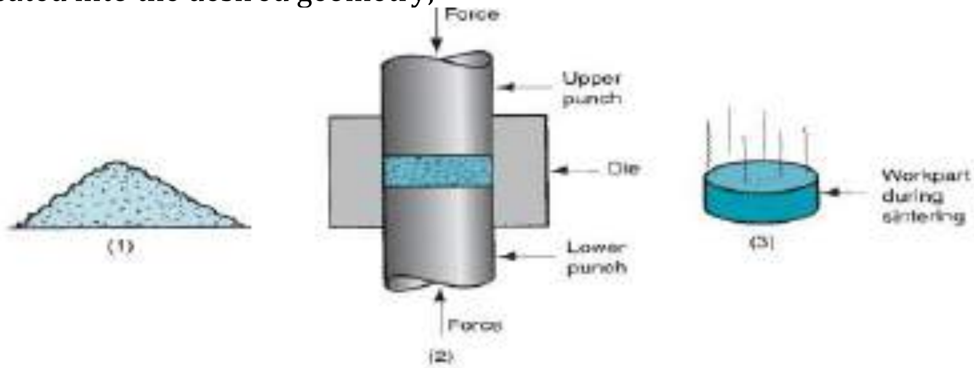


Shaping Processes Most shape processing operations apply heat, mechanical force, or a combination of these to effect a change in geometry of the work material. There are four categories:
(1) **solidification processes**, in which the starting material is a heated liquid solidifies to form the part geometry;

FIGURE 1.5 Casting and molding processes start with a work material heated to a fluid or semifluid state. The process consists of: (1) pouring the fluid into a mold cavity and (2) allowing the fluid to solidify, after which the solid part is removed from the mold.

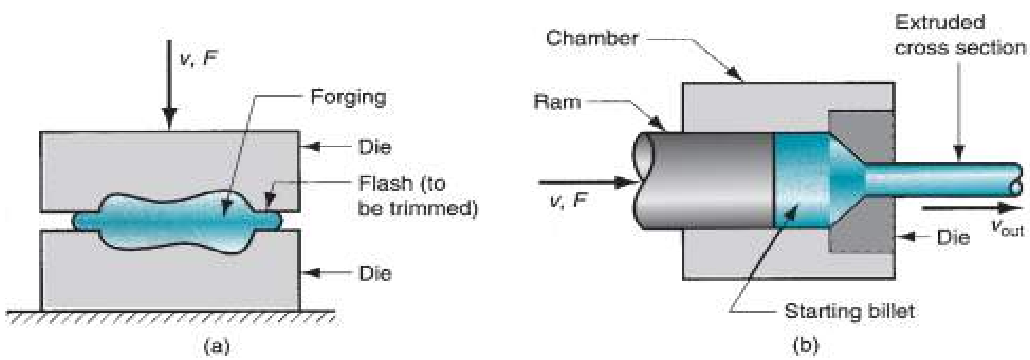


(2) **particulate processing**, in which the starting material is a powder, and the powders are formed and heated into the desired geometry;



(3) **deformation processes**, in which the starting material is a ductile solid (commonly metal) that is deformed to shape the part; and

FIGURE 1.7 Some common deformation processes: (a) **forging**, in which two halves of a die squeeze the workpart, causing it to assume the shape of the die cavity; and (b) **extrusion**, in which a billet is forced to flow through a die orifice, thus taking the cross-sectional shape of the orifice.



(4) **material removal processes**, in which the starting material is a solid (ductile or brittle), from which material is removed so that the resulting part has the desired geometry.

The most important processes in this category are machining operations such as turning, drilling, and milling, shown in Figure below. These cutting operations are most commonly applied to solid metals, performed using cutting tools that are harder and stronger than the work metal. Grinding is another common process in this category. Other **material removal processes** are known as nontraditional processes because they use lasers, electron beams, chemical erosion, electric discharges, and electrochemical energy to remove material rather than cutting or grinding tools.

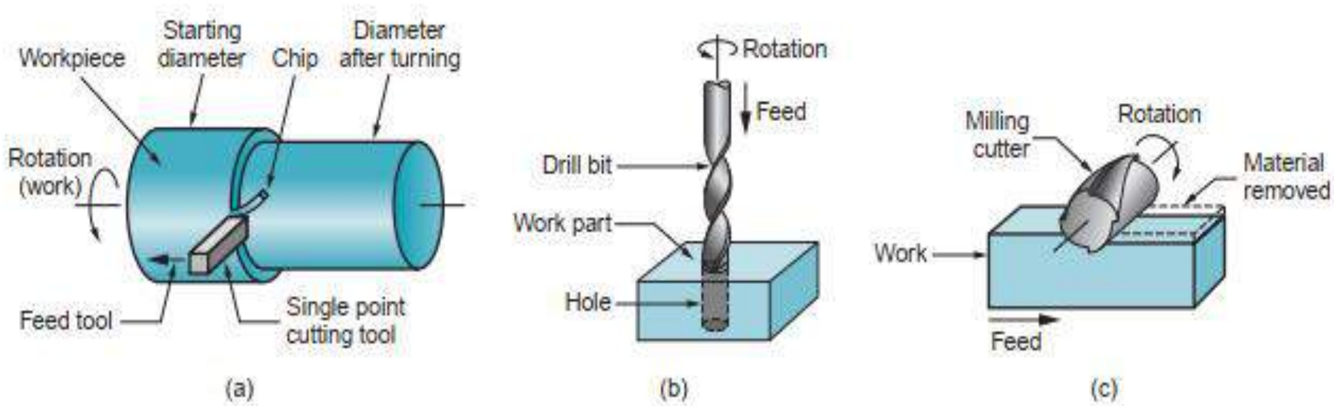


FIGURE 1.8 Common machining operations: (a) ***turning***, in which a single-point cutting tool removes metal from a rotating workpiece to reduce its diameter; (b) ***drilling***, in which a rotating drill bit is fed into the work to create a round hole; and (c) ***milling***, in which a workpart is fed past a rotating cutter with multiple edges.

5) Surface Processing Surface processing operations include (1) cleaning, (2) surface treatments, and (3) coating and thin film deposition processes.

ASSEMBLY OPERATIONS

The second basic type of manufacturing operation is assembly, in which two or more separate parts are joined to form a new entity. Components of the new entity are connected either permanently or semi permanently. **Permanent joining processes** include welding, brazing, soldering, and adhesive bonding. They form a joint between components that cannot be easily disconnected. Certain mechanical assembly methods are available to fasten two (or more) parts together in a joint that can be conveniently disassembled. The use of screws, bolts, and other threaded fasteners are important traditional methods in this category.

PRODUCTION MACHINES AND TOOLING

Manufacturing operations are accomplished using machinery and tooling (and people). Machine tools are among the most versatile of all production machines, the machine tool is the mother of all machinery.

Other **production machines** include presses for stamping operations, forge hammers for forging, rolling mills for rolling sheet metal, welding machines for welding, and insertion machines for inserting electronic components into printed circuit boards. The name of the equipment usually follows from the name of the process.

Production machinery usually requires tooling that customizes the equipment for the particular part or product.

TABLE 1.3 Production equipment and tooling used for various manufacturing processes.

Process	Equipment	Special Tooling (Function)
Casting	[a]	Mold (cavity for molten metal)
Molding	Molding machine	Mold (cavity for hot polymer)
Rolling	Rolling mill	Roll (reduce work thickness)
Forging	Forge hammer or press	Die (squeeze work to shape)
Extrusion	Press	Extrusion die (reduce cross-section)
Stamping	Press	Die (shearing, forming sheet metal)
Machining	Machine tool	Cutting tool (material removal)
		Fixture (hold workpart)
		Jig (hold part and guide tool)
Grinding	Grinding machine	Grinding wheel (material removal)
Welding	Welding machine	Electrode (fusion of work metal)
		Fixture (hold parts during welding)

[a] Various types of casting setups and equipment (Chapter 11).

PRODUCTION FACILITIES

Different types of facilities are required for each of the three ranges of annual production quantities.

Low-Quantity Production In the low-quantity range (1–100 units/year), the term job shop is often used to describe the type of production facility. This type of layout is referred to as a fixed-position layout, shown in Figure 1.9(a). The individual components of these large products are often made in factories in which the equipment is arranged according to **function or type**. This arrangement is called a **process layout**. The lathes are in one department, the milling machines are in another department, and so on, as in Figure 1.9(b).

Medium Quantity Production In the medium-quantity range (100–10,000 units annually), two different types of facility are distinguished, depending on product variety. When product variety is hard, the usual approach is batch production, in which a batch of one product is made. that is, the cell specializes in the production of a given set of similar parts, according to the principles of group technology . The layout is called a cellular layout, depicted in Figure 1.9(c).

High Production The high-quantity range (10,000 to millions of units per year) is referred to as mass production. The situation is characterized by a high demand rate for the product, and the manufacturing system is dedicated to the production of that single item. Two categories of mass production can be distinguished: quantity production and flow line production. Quantity production involves the mass production of single parts on single pieces of equipment.

MANUFACTURING SUPPORT SYSTEMS: To operate its facilities efficiently, a company must organize itself to design the processes and equipment, plan and control the production orders, and satisfy product quality requirements. Manufacturing support functions are often carried out in t the following:

Manufacturing engineering. This department is also involved in designing and ordering the machine tools and other equipment used by the operating departments to accomplish processing and assembly.

Production planning and control. This department is responsible for solving the logistics problem in manufacturing ordering materials and purchased parts, scheduling production, and making sure that the operating departments have the necessary capacity to meet the production schedules.

Quality control. Producing high-quality products should be a top priority of any manufacturing firm in today's competitive environment.