• **Process** in which molten metal flows by gravity or other force into a mold or die where it solidifies in the shape of the mold cavity.

• The term **casting** also applies to the part made in the process.
Steps of Casting Process

- Melt
- *Pour / force* molten material (liquid) into hollow cavity (mold or die) of the desired shape.
- *Cool / Solidify*
- Remove
- Finish
Heating the Metal

- Heating furnaces are used to heat the metal to molten temperature sufficient for casting
Pouring the Molten Metal

• For this step to be successful, metal must flow into all regions of the mold, most importantly the main cavity, before solidifying.

• Factors that determine success:
  – Pouring temperature
  – Pouring rate
  – Lack of turbulence
Shrinkage of a cylindrical casting during solidification and cooling: (0) starting level of molten metal immediately after pouring; (1) reduction in level caused by liquid contraction during cooling (dimensional reductions are exaggerated for clarity in sketches)
(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 the solid metal (dimensional reductions are exaggerated for clarity in our sketches)
Riser

Shrinkage cavity

Riser
(a) External chill to encourage rapid freezing of the molten metal in a thin section of the casting; and (b) the likely result if the external chill were not used.
Categories of Casting Process

- **Expendable mold processes** – uses an expendable mold which must be destroyed to remove casting
  - Mold materials: sand, plaster, and similar materials, plus binders
- **Permanent mold processes** – uses a permanent mold which can be used many times to produce many castings
  - Made of metal (or, less commonly, a ceramic refractory material)
I - Sand Casting
Sand is used as mold material.
• Sand grains are mixed with small amounts of other materials:
  – To improve moldability
  – To increase cohesive strength
• Patterns are used to prepare molds.
• To remove pattern, mold should be made, at least, in two pieces.
• A new mold is prepared for each casting.
Two forms of mold: (a) open mold, simply a container in the shape of the desired part; and (b) closed mold, in which the mold geometry is more complex and requires a gating system (passageway) leading into the cavity.
Mold consists of two halves:
- **Cope**: upper half of mold
- **Drag**: bottom half of the mold

Mold halves are contained in a box, called a **flask**

The two halves separate at the **parting line**
Pouring

Ladle

Manual Pouring

Automatic Pouring Machine
**Patterns**

- Pattern is the *duplicate* of the part to be cast.
- It should be modified to take the *allowances* into consideration.
- The most commonly used pattern materials are wood, aliminum, magnesium, and certain hard plastics.
Split Patterns
Pattern Allowances

Modifications that must be incorporated to a pattern are called *allowances*.

- **Shrinkage allowance**: Pattern should be larger than the desired shape to compensate for shrinkage during solidification.
- **Finish allowance**: Pattern must be made larger if a better surface is to be obtained via machining.
- **Distortion allowance**
- **Rap (shake) allowance**: To facilitate removal, pattern is shaked, which in turn enlarges the mold. Thus, pattern should be made smaller.
Pattern Allowances

- **Draft (taper) allowance**: Taper is necessary to facilitate pattern’s withdrawal. Otherwise, sand particles may break away from the mold due to the interface friction. Hence, pattern should be made larger.
Molding machines are generally of **jolt** (sarsma) and **squeeze** type.

Generally, **match-plate** patterns are used with molding machines.

For large castings, **sandslinger** (kum püskürtme), which impels the sand into the mold with high velocity to pack it to the desired hardness is employed.
Jolt and Squeeze type Molding Machine
Pit-type Mold
Cores

- Cores are used to obtain hollow or reentrant sections in castings.
- Sections of sand, which protrude into the hole in the pattern, are called cores.
- There are two basic types of cores used in sand casting:
  - **Green-sand cores** (kum maça): Made up of the same sand as the rest of the mold. They are weak.
  - **Dry-sand cores** (Sert kum maça): Made by mixing sand with some binding agent and then packing it into a core box containing cavity of the desired shape.
Cores

Parting line
Hole machined later
Green sand cores
Dry sand core
Dry sand core

(a)   (b)   (c)   (d)
Cores
Dry Sand Core - Core Box
When dry-sand cores are used, it is usually necessary to provide recesses in the mold into which the ends of the core can be placed to provide support and/or hold them in position.

These recesses are known as core prints (maça omuzu).
Sand-Cast Products
***kumdokumvideo.wmv***

** FORMING/casting (SME/Willey’s video)**
Shell Molding

(a) Dump box
(b) Box and pattern inverted
(c) Shell
(d) Dump box removed
(e) Matched shells

Hot pattern
Handles
Sand with resin binder
Box righted
Ejector pin
Metal shot
Clamp
Flask
Shell Molding

- Better surface finish than that of sand casting,
- Better dimensional accuracy,
- Low labor cost,
- Low machining cost,
- High productivity,
- Requires expensive machines.
Shell Molding

Metal Patterns

Shell Molds

Product
Full-Mold Process

- Useful for complex castings when pattern withdrawal is not easy or pattern cost is too high.
- Useful for a single casting or a few castings (prototypes)
- The pattern is made of foamed (expanded) **polystyrene**, which remains in the mold during pouring.
- When molten material is poured, the heat vaporizes the pattern almost instantaneously.
When compared to wood, foamed polystyrene is relatively inexpensive and light. It can be easily cut and glued to obtain the desired workpiece geometry, sprue, runner, riser, etc.

Since pattern is not withdrawn, no draft allowance is required.
Full-Mold Process

Pattern

Blind Risers

Product
II – Permanent Mold Casting
Permanent Mold Casting

- Sand casting has two disadvantages:
  - A new mold is necessary for each casting.
  - Dimensional variations from one casting to another.
- In permanent mold casting, reusable molds are made from metal or graphite.
- Method is limited mostly to lower melting-point metals and alloys:
  - Aluminum
  - Magnesium
  - Copper-based alloys
Mold

A form of cavity into which molten metal is poured to produce a desired shape.

Die

A metal block used in forming materials by casting, molding, stamping, threading, or extruding.

( => A considerable force is acting on it.)
1) Nonferrous Permanent Mold Casting

- **Gravity** is used to introduce the metal.
- Molds are made from **steel or cast iron**:
  - non-Fe metals and alloys are cast.
- For *casting steel or cast iron*, **graphite molds** are used.
- Molds are **hinged**:
  - Opened and closed accurately and rapidly.
- **Sand cores or retractable metal cores** can be used to increase the complexity of the casting.
2) Pressure Pouring
3) Die Casting

- Molten metal is forced into the die by pressure and held under pressure during solidification.
- Very excellent details and fine sections can be obtained while extending die-life.
- Mostly non-ferrous metals and alloys are cast.
- It is also possible to cast ferrous metals.
Some advantages of die casting are

- Excellent accuracy
- Smooth surface finish
- Low labor cost
- High production rate.
Dies used in Die Casting

- Dies with at least **two pieces** are made from alloy steel.
- **Die sections include cooling water passages and knock-out pins.**
- **When necessary, metal cores are used in the dies.**
  - Mechanisms are utilized to retract them before opening the die for removal of the casting.
- **Small vents or overflows may be used to discharge trapped air from the cavity.**
- **Die costs is in excess of 5000 TL, often over 15,000 TL, up to some 100,000 TLs.**
Die Casting - Products
Two types of machines are commonly used in die casting:

- Hot Chamber Machines
- Cold Chamber Machines
Hot Chamber Machines

- Referred to as **Gooseneck** type machines.
- Metal is **melted** within the machine.
- **Fast** operation.
- **Cannot** be used for higher melting-point metals **above** 450°C (e.g. **brass**, **bronze**, **magnesium (Mg))**.
- **Mainly used for** **zinc (Zn), tin (Sn) and lead (Pb) base alloys**.
- **When used with aluminum**, there is a tendency to pick up some **iron** from the equipment.
- **Lower injection pressures and speed** can be achieved, so castings may be less dense.
- **Higher maintenance costs**.
Hot Chamber Machines
Cold Chamber Machines

- Metal is melted outside the machine and is fed into the cold chamber.
- Metal is forced into the die by a plunger. Injection pressures over 70 MPa can be obtained from this type of machine.
- There is little tendency for iron pick-up.
Cold Chamber Die Casting Machine
4) Centrifugal Casting
Centrifugal Casting
Centrifugal Casting - Vertical

Paraboloid A

Paraboloid B

Spinning table
Centrifuging
III – Plaster Mold Casting
Plaster Mold Casting

- Plaster molds are used:
  - Molds are made from gypsum plaster with:
    - Talc
    - Terra alba or
    - Magnesium oxide
  - Limited to casting of lower-melting-point alloys (Al, Mg, Cu, etc.)
  - Not permeable
  - Parts with relatively intricate geometry
  - Better surface finish and dimensional accuracy
  - Capability to make thinner sections
1) Investment Casting

- **Types**
  - *Flask type*
  - *Shell type*

- **Complex and expensive process**

- **But unlimited complex shapes can be obtained.**
  - *Intricate shapes*
  - *Very thin sections*

- **Dimensional tolerances are excellent.**

- **Very good surface quality.**
1a) Investment Flask Casting

1. Wax or plastic is injected into die to make a pattern.
2. Patterns are gated to a central sprue.
3. A metal flask is placed around the pattern cluster.
4. Flask is filled with investment mold slurry.
5. After mold material has set and dried, patterns are melted out of mold.
6. Hot molds are filled with metal by gravity, pressure, vacuum or centrifugal force.
7. Mold material is broken away from castings.
8. Castings are removed from sprue, and gate stubs ground off.
1b) Investment Shell Casting

1. Wax or plastic is injected into die to make a pattern
2. Patterns are gated to a central sprue
3. Pattern clusters are dipped in ceramic slurry
4. Refractory grain is sifted onto coated patterns. Steps 3 and 4 are repeated several times to obtain desired shell
5. After mold material has set and dried patterns are melted out of mold
6. Hot molds are filled with metal by gravity, pressure, vacuum or centrifugal force
7. Mold material is broken away from castings
8. Castings are removed from sprue, and gate stubs ground off

To shipping
Investment Casting - Products
*** FORMING/Casting-investment casting
(SME/Wiley’s video)***
2) Shaw Process

- Slurry like mixture is poured over the pattern.
  - Refractory aggregate
  - Hydrolyzed ethyl silicate
  - Jelling agent

- Mixture sets in a rubbery jell so that the pattern can be stripped from the mold.

- Mold has sufficient strength to return its original shape.
The mold is ignited to burn off the volatile elements in the mix.
It is then brought to a red heat in a furnace.
This firing makes the mold rigid and hard.
At the same time, micro-cracks are formed. They provide
- Excellent permeability
- Good collapsibility
Shaw Process - Properties

- Casting of all sizes,
- Produces excellent surface finish,
- Excellent detail,
- High dimensional accuracy,
- Cheaper than investment casting.
Shaw Process - Products
Cleaning and Finishing of Castings

• Removal of cores:
  – *Shaking* or dissolving the core binder

• Removal of gates and risers:
  – For small castings, they are *knocked off*.
  – For larger ones, they are *cut off* by
    • Cut-off wheel
    • Power hacksaw / bandsaw
    • Oxy-acetylene torch
Cleaning and Finishing of Castings

• Removal of fins and rough spots from the surface:
  – *Tumbling* machine (for medium castings)
  – *Cleaning* chamber (for larger castings)
  – *Manually* (for extra large castings)

• Cleaning the surface,

• Repearing any defects,
  – *Arc-welding*
Cleaning and Finishing of Castings
Cleaning and Finishing of Castings
Heat Treatment of Castings

• Steel castings almost always given a full anneal.

• Nonferrous castings of some types are heat-treated to put them in a normalized (stress) condition.