WORKSHOP PRACTICE

CASTING

Semester: 1st (Fall 2013)

INDUSTRIAL ENGINEERING DEPARTMENT

COURSE INSTRUCTOR:
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Learning Objectives

- **At the end of this lecture, you will be able to:**
- Know about sand casting
- Pattern Making
- Components of moulds

Introduction

- **Sand casting**, also known as **sand molded casting**, is a metal casting process characterized by using sand as the mold material.

- The term "sand casting" can also refer to an object produced via the sand casting process. Sand castings are produced in specialized factories called foundries.

- Over 70% of all metal castings are produced via a sand casting process

Basic process

There are six steps in this process

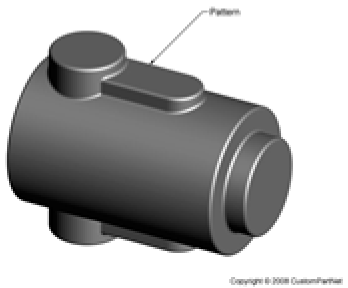
1) Place a pattern in sand to create a mold.
2) Incorporate the pattern and sand in a gating system.
3) Remove the pattern.
4) Fill the mold cavity with molten metal
5) Allow the metal to cool
6) Break away the sand mold and remove the casting.

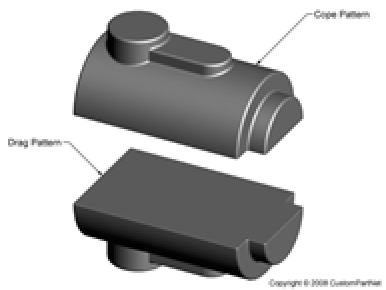
Pattern Making

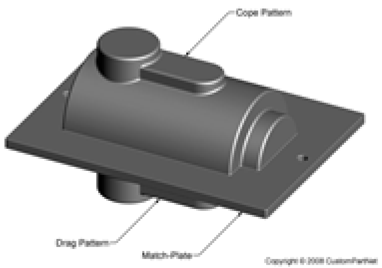
The main tooling for sand casting is the pattern that is used to create the mold cavity.

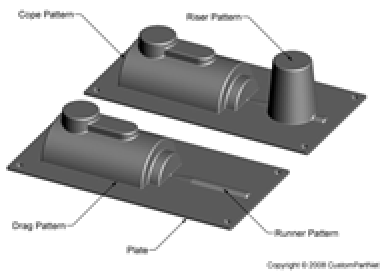
A pattern for a part can be made many different ways, which are classified into the following four types:

1) *Solid pattern*
2) Split pattern
3) *Match-plate pattern*
4) *Cope and drag pattern*

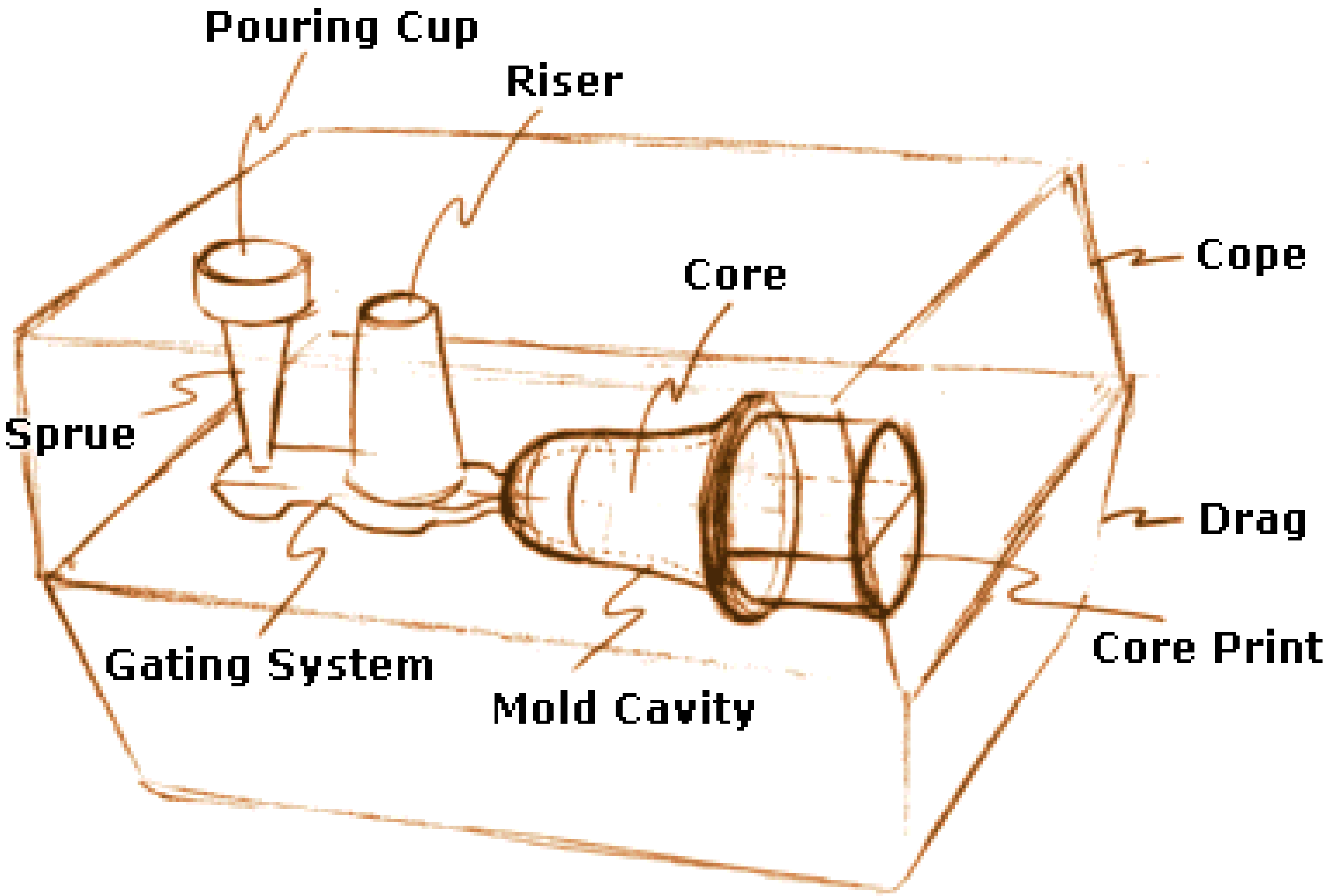








Typical Components of a Two-part Sand Casting Mold



Sprues and Runners

- The molten material is poured in the pouring cup, which is part of the gating system that supplies the molten material to the mold cavity.

- The vertical part of the gating system connected to the pouring cup is the **sprue**.

- The horizontal portion is called the **runners** and finally to the multiple points where it is introduced to the mold cavity called the **gates.**

Riser

- A **riser**, also known as a **feeder**, is a reservoir built into a metal casting mold to prevent cavities due to shrinkage.

MOLD MATERIALS

Mold Materials

- There are four main components for making a sand casting mold:

  1) *Base sand*
  2) *Binder*
  3) *Additives*
  4) A p*arting compound*

1. Types of Sand Molds

- ***Greensand mold*** **-** Greensand molds use a mixture of sand, water, and a clay or binder. Typical composition of the mixture is 90% sand, 3% water, and 7% clay or binder + sludge. Greensand molds are the least expensive and most widely used.

- ***Skin-dried mold*** **-** A skin-dried mold begins like a greensand mold, but additional bonding materials are added and the cavity surface is dried by a torch or heating lamp to increase mold strength. Doing so also improves the dimensional accuracy and surface finish, but will lower the collapsibility. Dry skin molds are more expensive and require more time, thus lowering the production rate.

1. Types of Sand Molds

- ***Dry sand mold* -** In a dry sand mold, sometimes called a cold box mold, the sand is mixed only with an organic binder. The mold is strengthened by baking it in an oven. The resulting mold has high dimensional accuracy, but is expensive and results in a lower production rate.
- ***No-bake mold* -** The sand in a no-bake mold is mixed with a liquid resin and hardens at room temperature.

Molding Sand Characteristics

- **Refractoriness** — This refers to the sand's ability to withstand the temperature of the liquid metal being cast without breaking down.

- **Chemical inertness** — The sand must not react with the metal being cast. This is especially important with highly reactive metals, such as magnesium and titanium.

- **Permeability** — This refers to the sand's ability to exhaust gases. This is important because during the pouring process many gases are produced, such as hydrogen, nitrogen, carbon dioxide, and steam, which must leave the mold otherwise casting defects, such as blow holes and gas holes.

Molding Sand Characteristics

- **Surface finish** — The size and shape of the sand particles defines the best surface finish achievable, with finer particles producing a better finish. However, as the particles become finer (and surface finish improves) the permeability becomes worse.

- **Cohesiveness** (or **bond**) — This is the ability of the sand to retain a given shape after the pattern is removed.

- **Flowability** – The ability for the sand to flow into intricate details and tight corners without special processes or equipment.

Molding Sand Characteristics

- **Collapsibility** — This is the ability of the sand to be easily stripped off the casting after it has solidified. Sands with poor collapsibility will adhere strongly to the casting. When casting metals that contract a lot during cooling or with long freezing temperature ranges a sand with poor collapsibility will cause cracking and hot tears in the casting.

- **Availability/cost** — The availability and cost of the sand is very important because for every ton of metal poured, three to six tons of sand is required.

2. Binders

Binders

- *Binders* are added to a base sand to bond the sand particles together (i.e. it is the glue that holds the mold together).
- **Clay and water**
  A mixture of clay and water is the most commonly used binder.
- **Oil**
  Oils, such as linseed oil, other vegetable oils and marine oils, used to be used as a binder, however due to their increasing cost, they have been mostly phased out.
- **Resin**
  Resin binders are natural or synthetic high melting point gums. The two common types used are urea formaldehyde (UF) and phenol formaldehyde (PF) resins

3. Additives

- Additives are added to the molding components to improve: surface finish, dry strength, refractoriness

4. Parting Compound

- To get the pattern out of the mold, prior to casting, a parting compound is applied to the pattern to ease removal. They can be a liquid or a fine powder (particle diameters between 75 and 150 micrometres (0.0030 and 0.0059 in)).
- Common powders include talc, graphite, and dry silica.

Process

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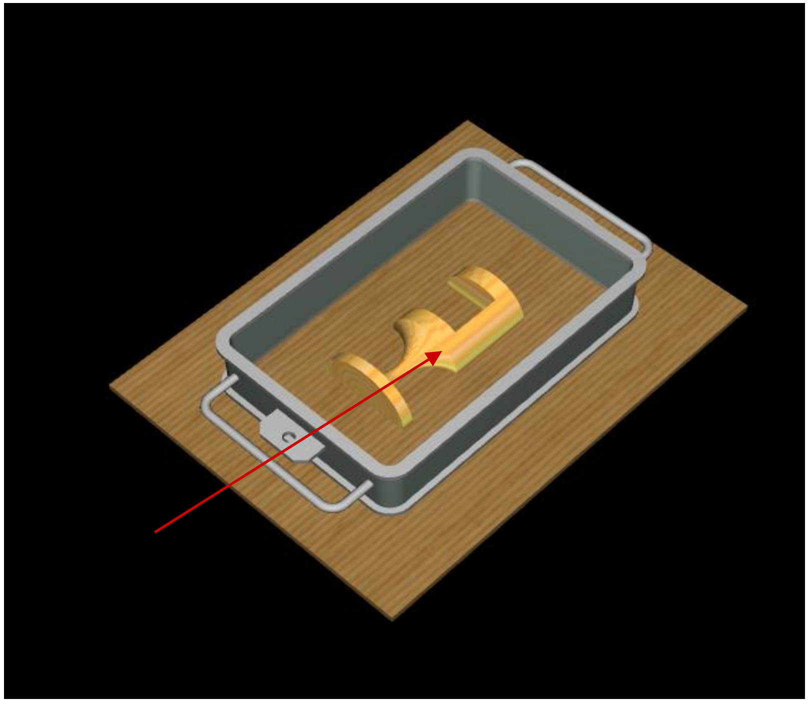

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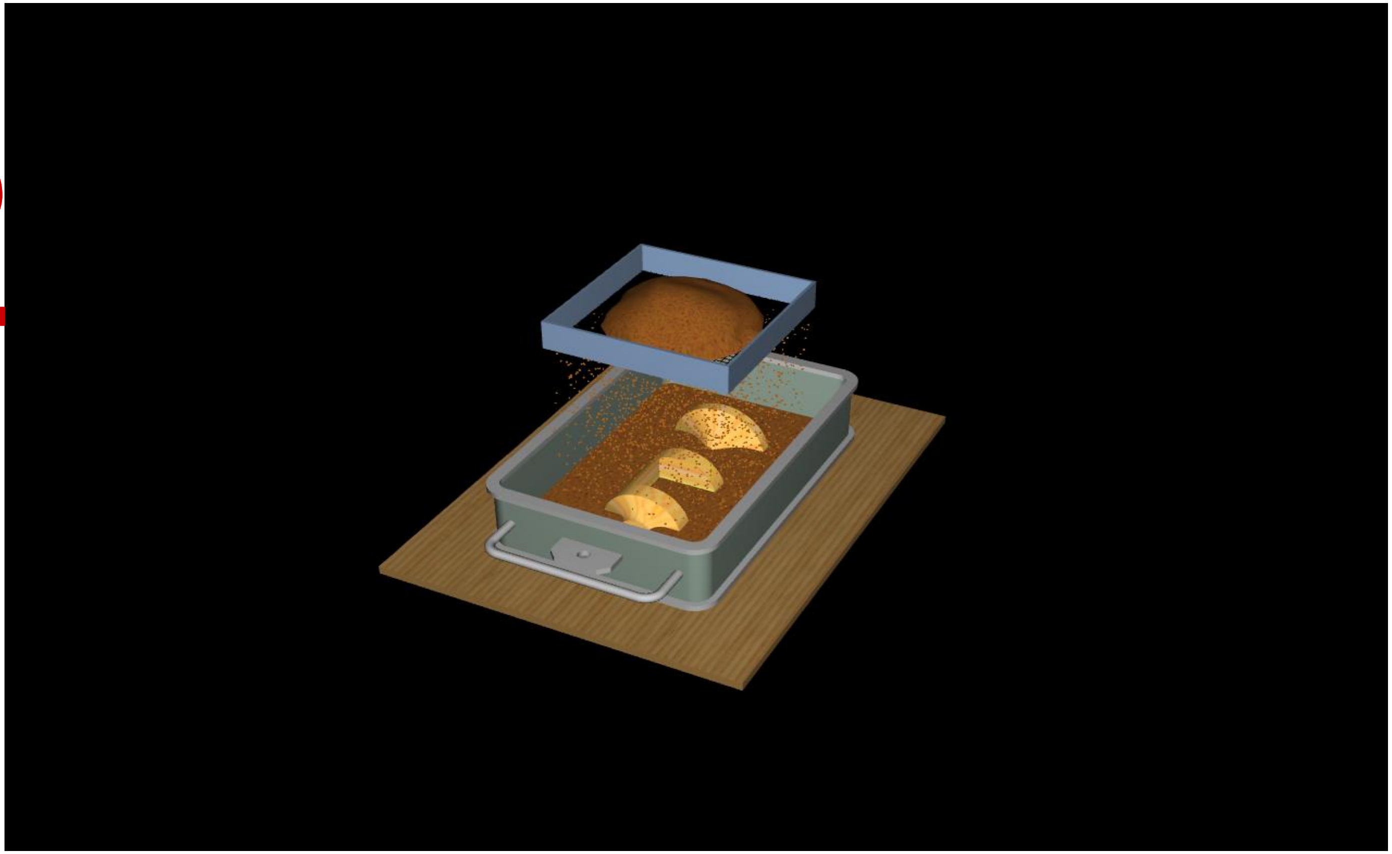

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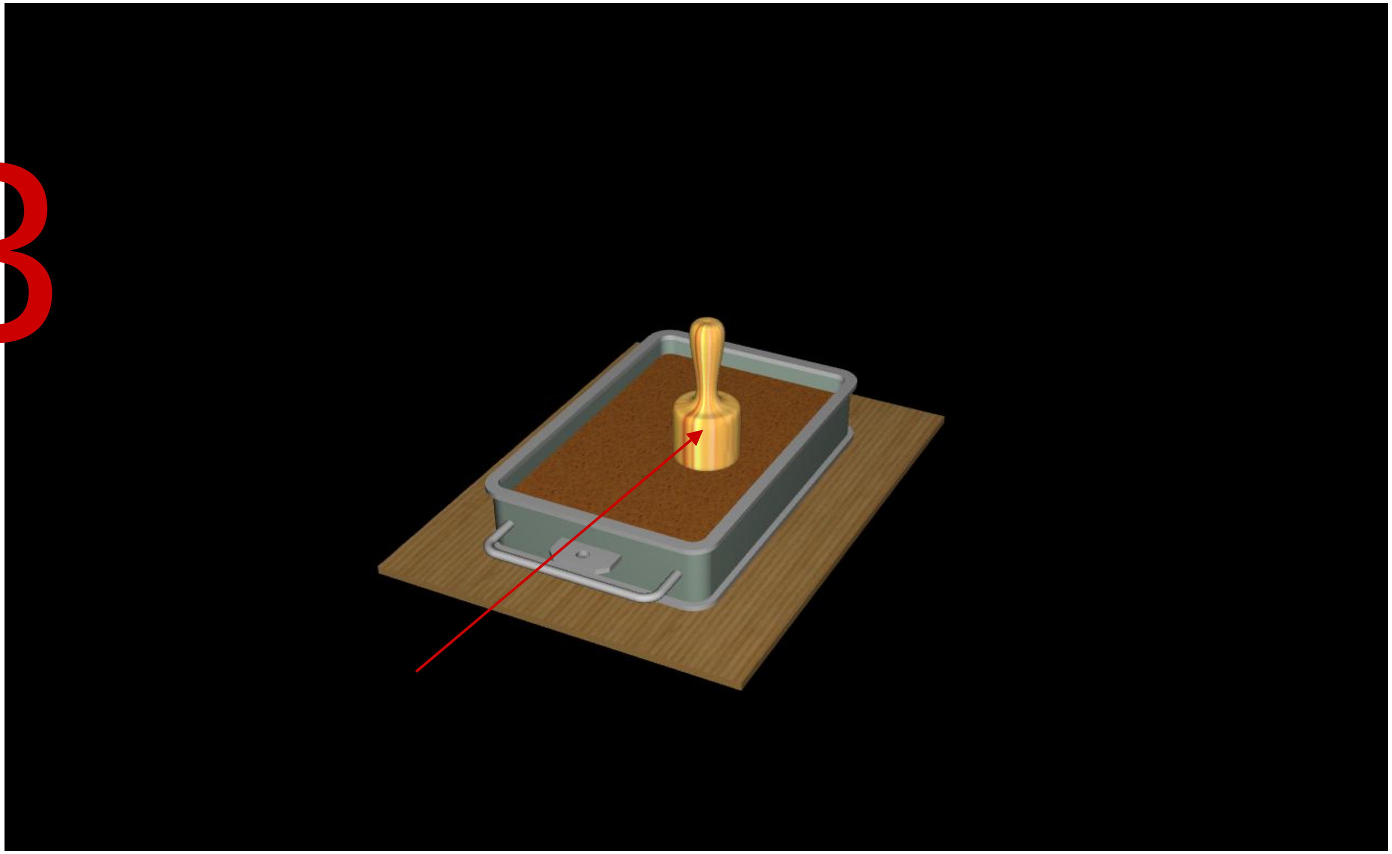

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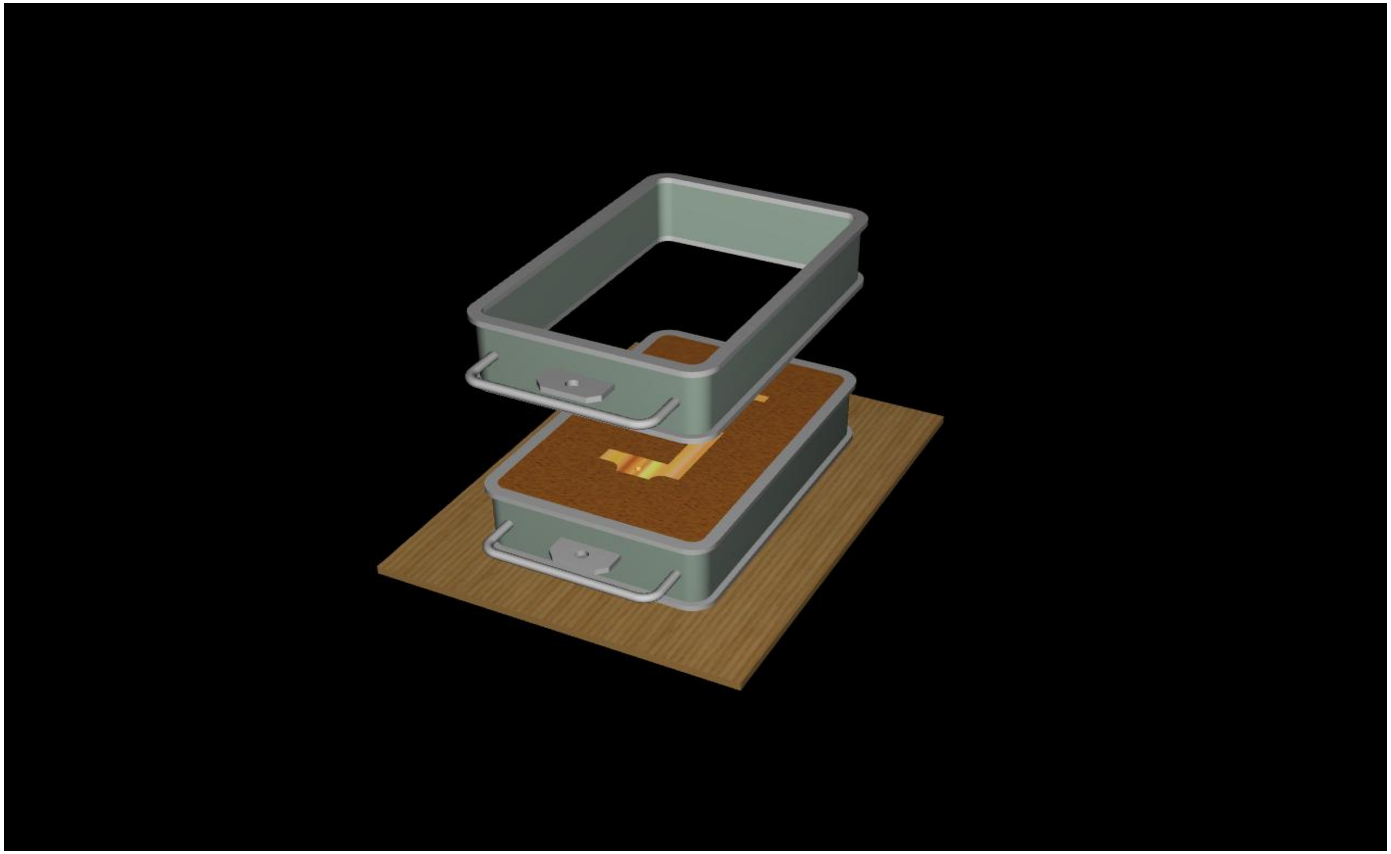

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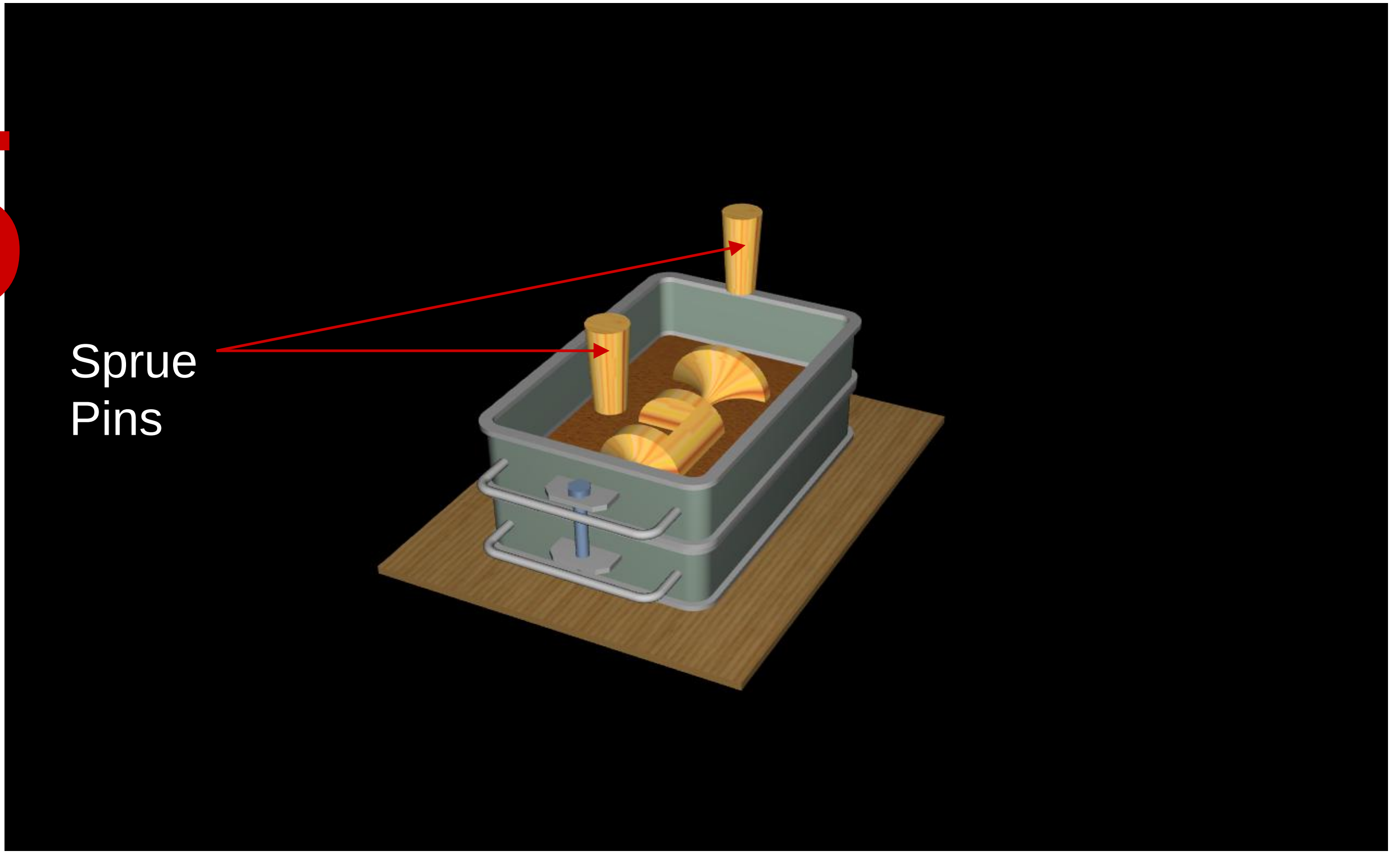

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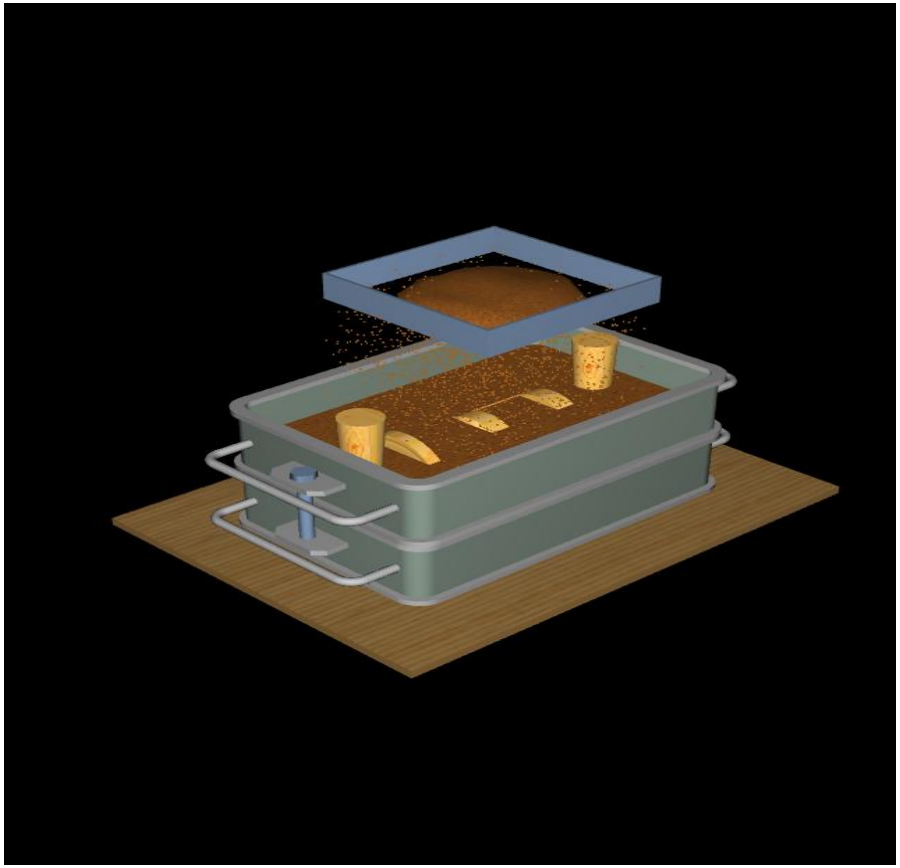

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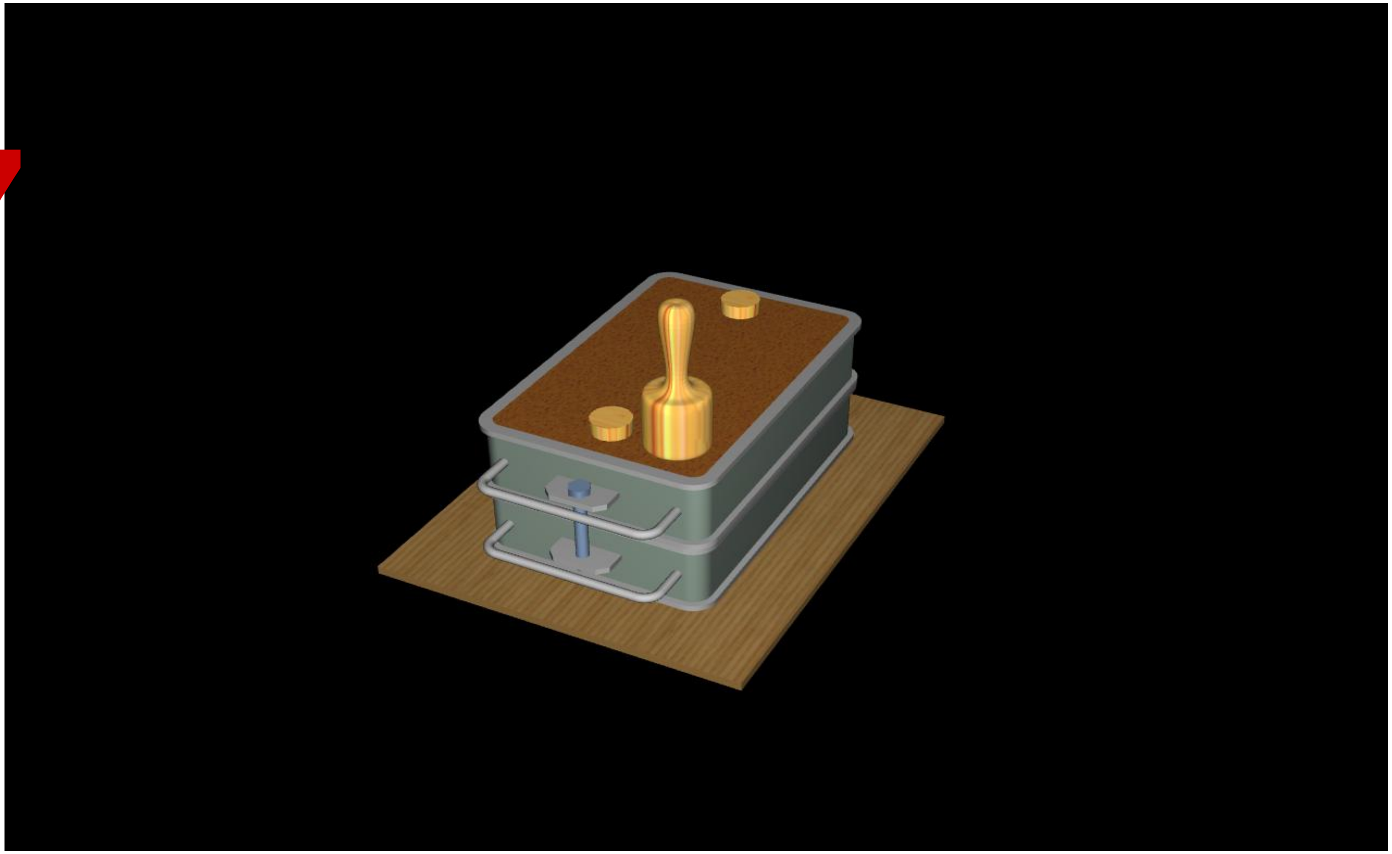

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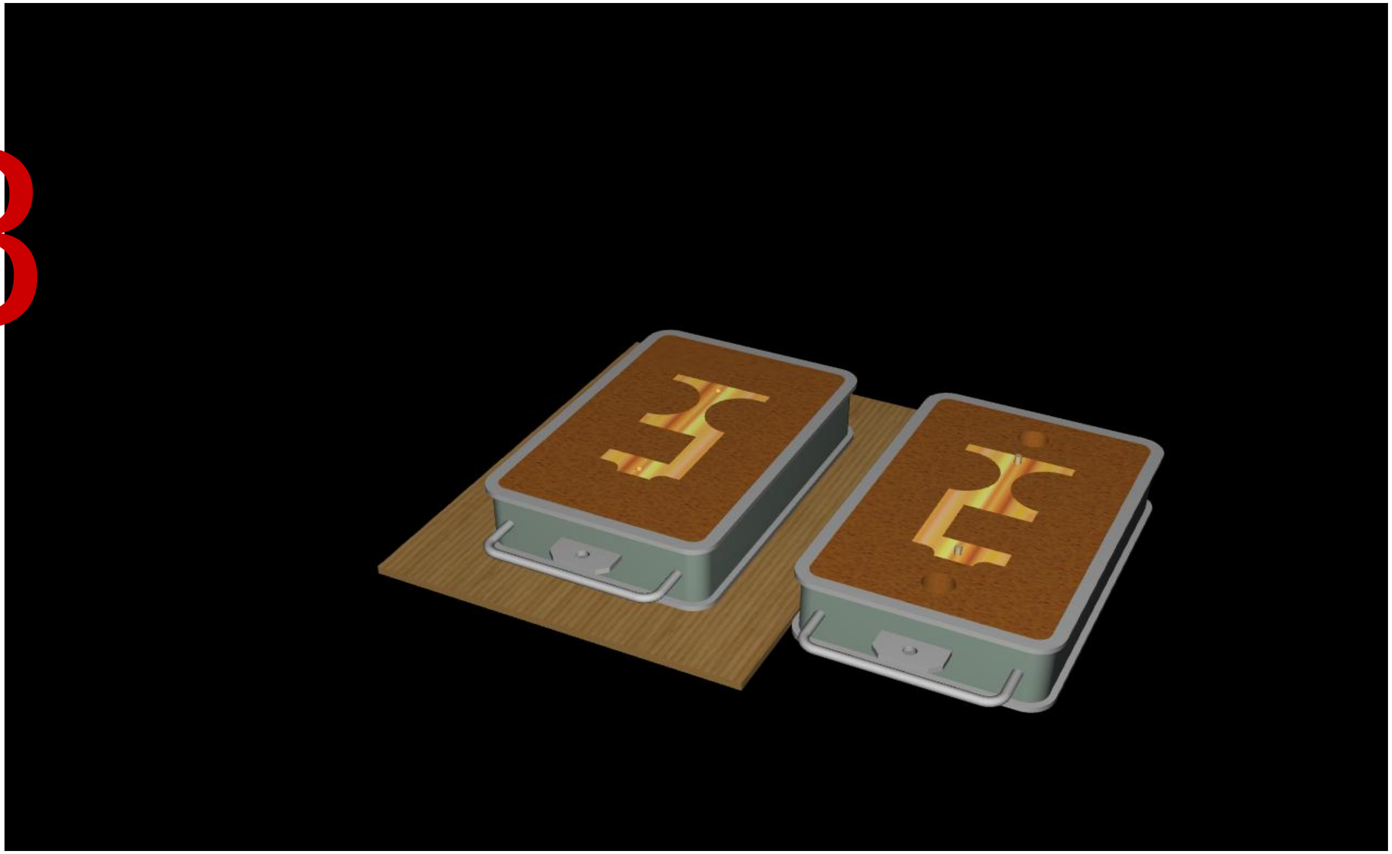

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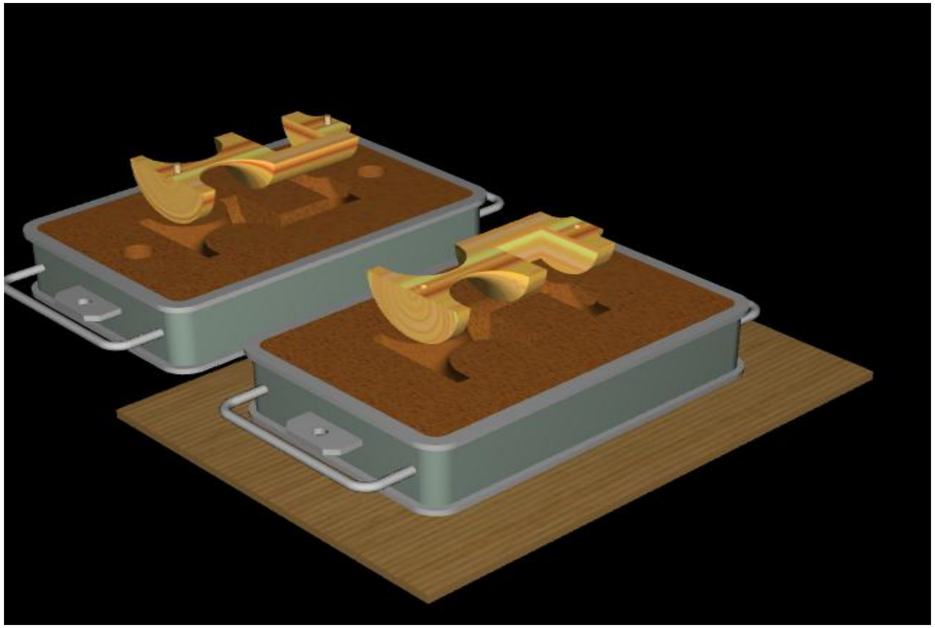

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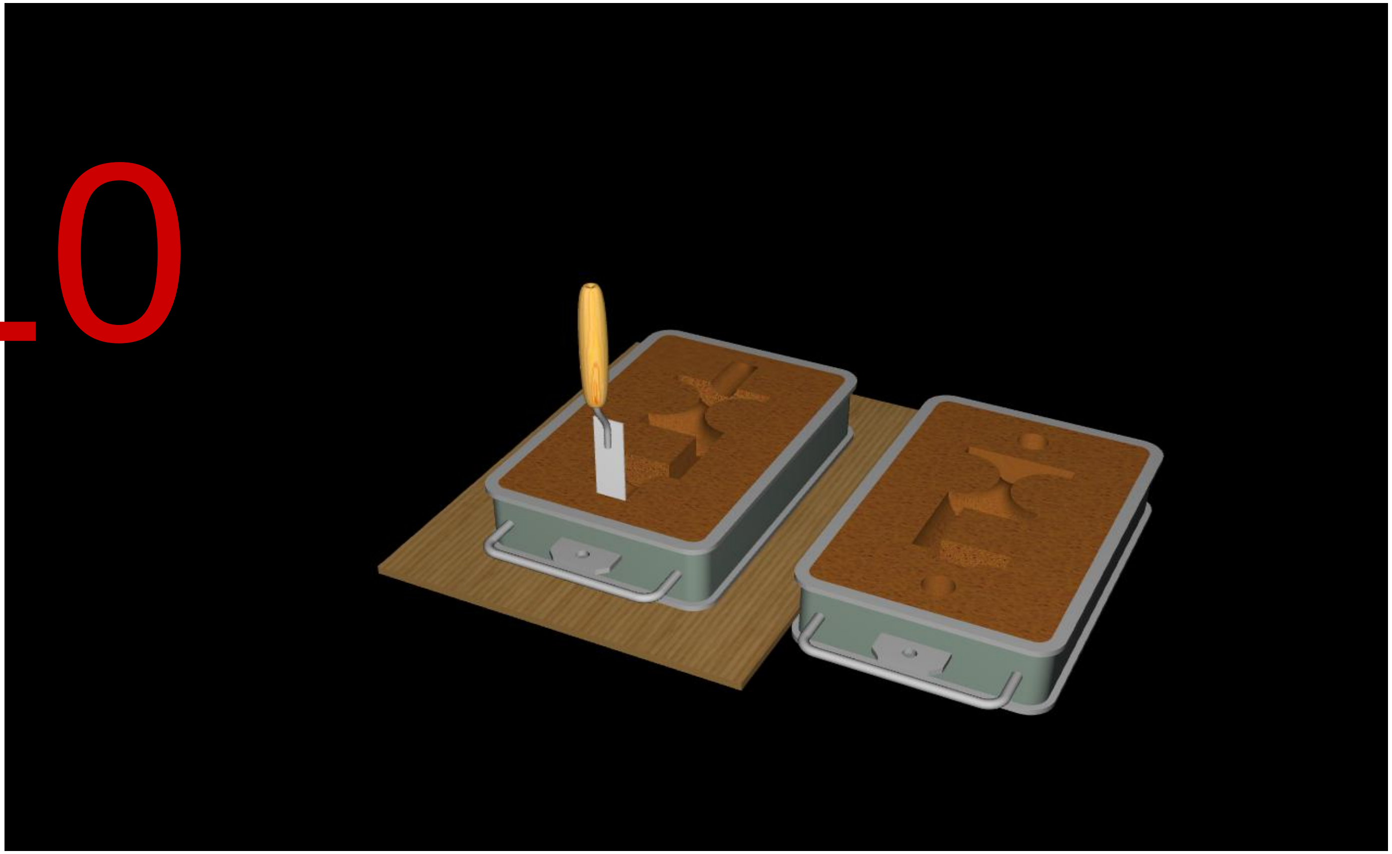

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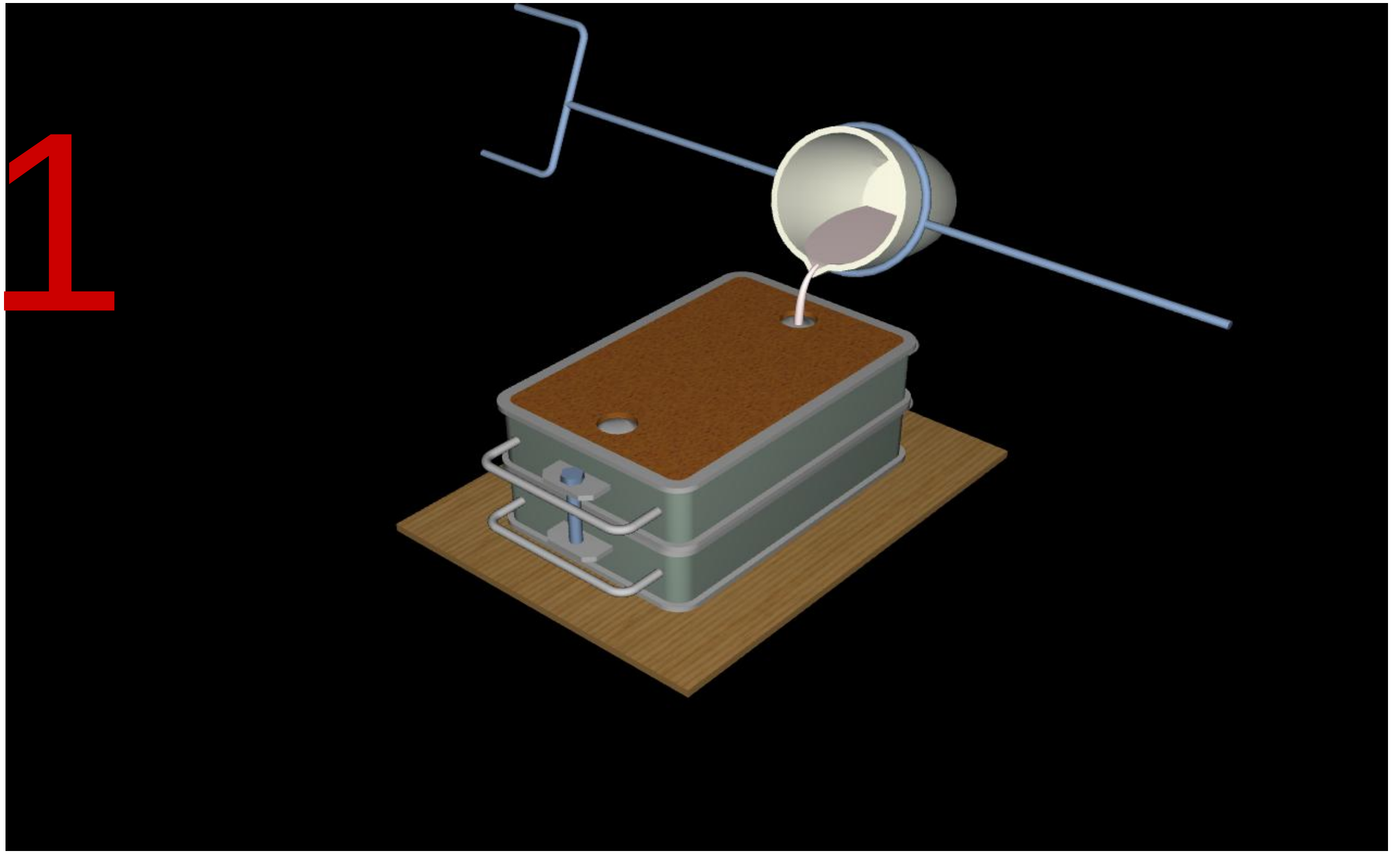

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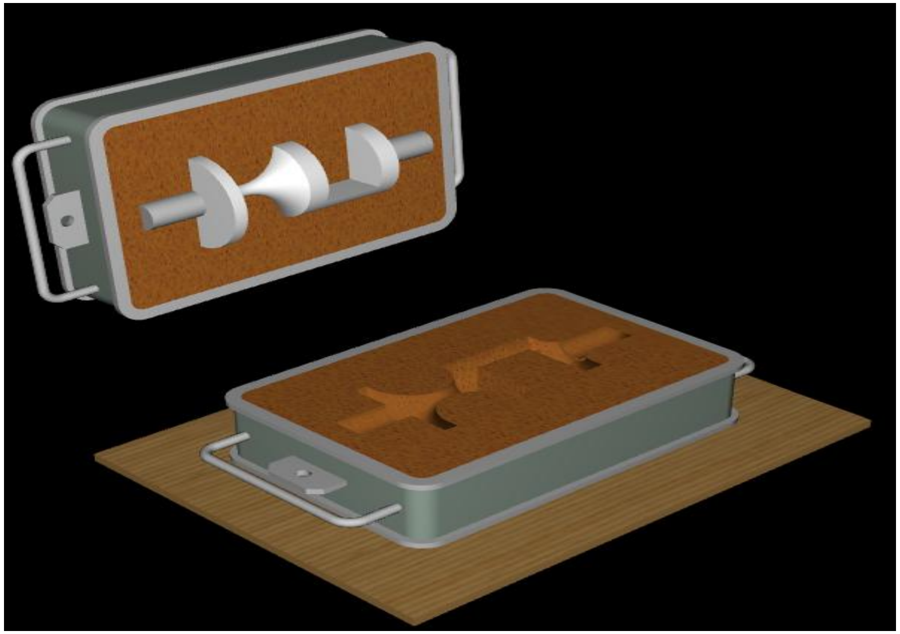

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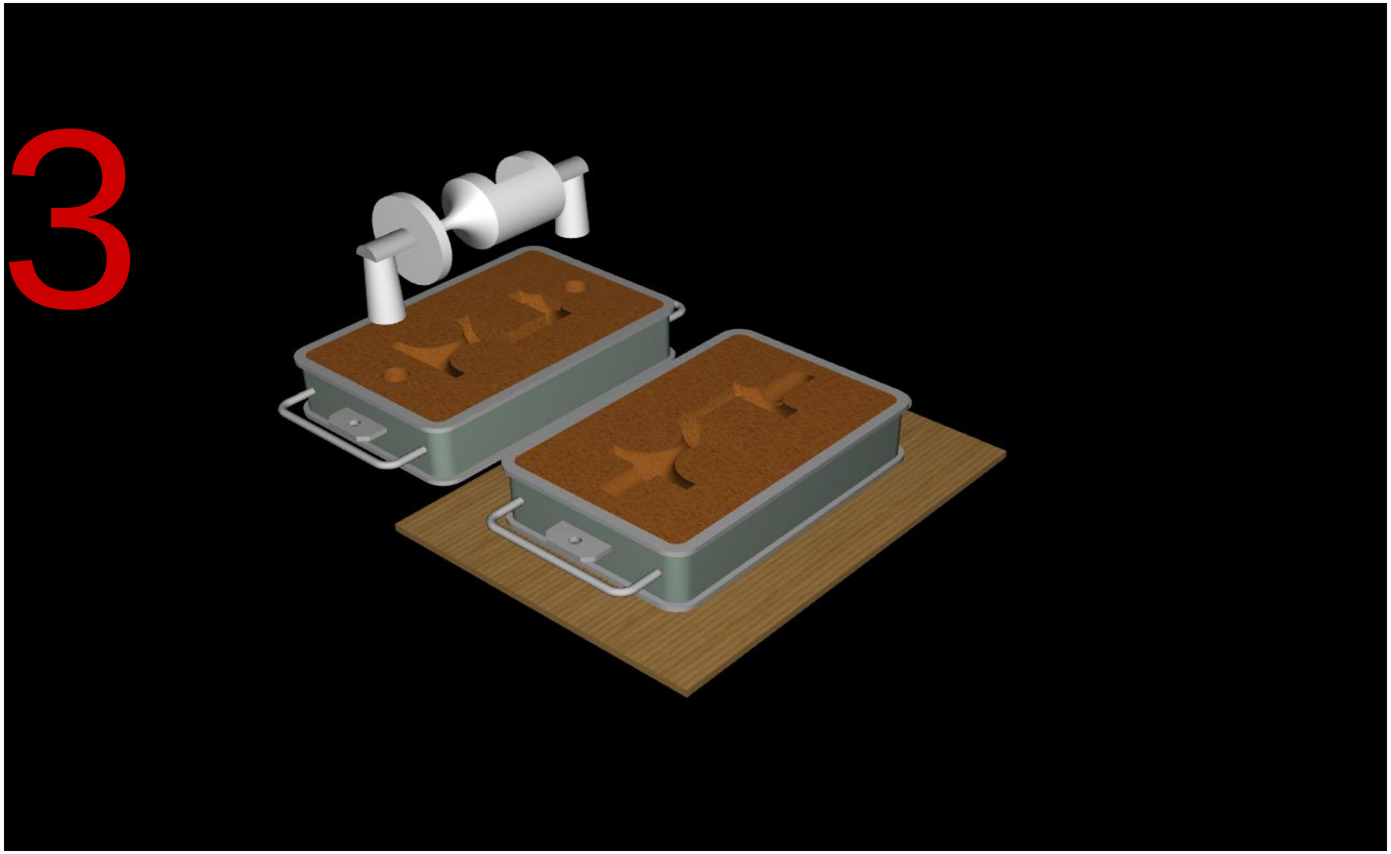


Sand Casting Video

- Sand Casting .FLV

Metal Casting Processes

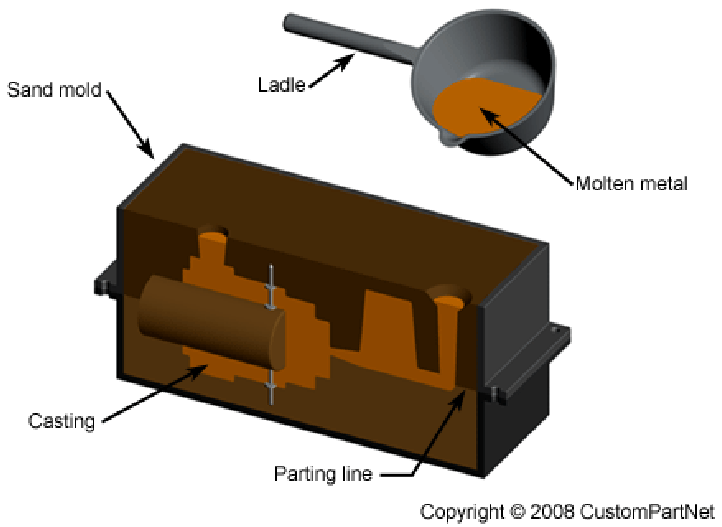
1. Sand Casting
2. Other Expendable Mold Casting Processes
3. Permanent Mold Casting Processes
4. Foundry Practice
5. Casting Quality
6. Metals for Casting
7. Product Design Considerations

Two Categories of Casting Processes

1. Expendable mold processes - mold is sacrificed to remove part
   - Advantage: more complex shapes possible
   - Disadvantage: production rates often limited by time to make mold rather than casting itself
2. Permanent mold processes - mold is made of metal and can be used to make many castings
   - Advantage: higher production rates
   - Disadvantage: geometries limited by need to open mold

Other Expendable Mold Processes

- Shell Molding
- Vacuum Molding
- Expanded Polystyrene Process
- Investment Casting
- Plaster Mold and Ceramic Mold Casting



Permanent Mold Casting Processes

- Economic disadvantage of expendable mold casting: a new mold is required for every casting.
- In permanent mold casting, the mold is reused many times .
- The processes include:
  - Basic permanent mold casting
  - Die casting
  - Centrifugal casting

The Basic Permanent Mold Process

Uses a metal mold constructed of two sections designed for easy, precise opening and closing

- Molds used for casting lower melting point alloys are commonly made of steel or cast iron
- Molds used for casting steel must be made of refractory material, due to the very high pouring temperatures

Permanent Mold Casting

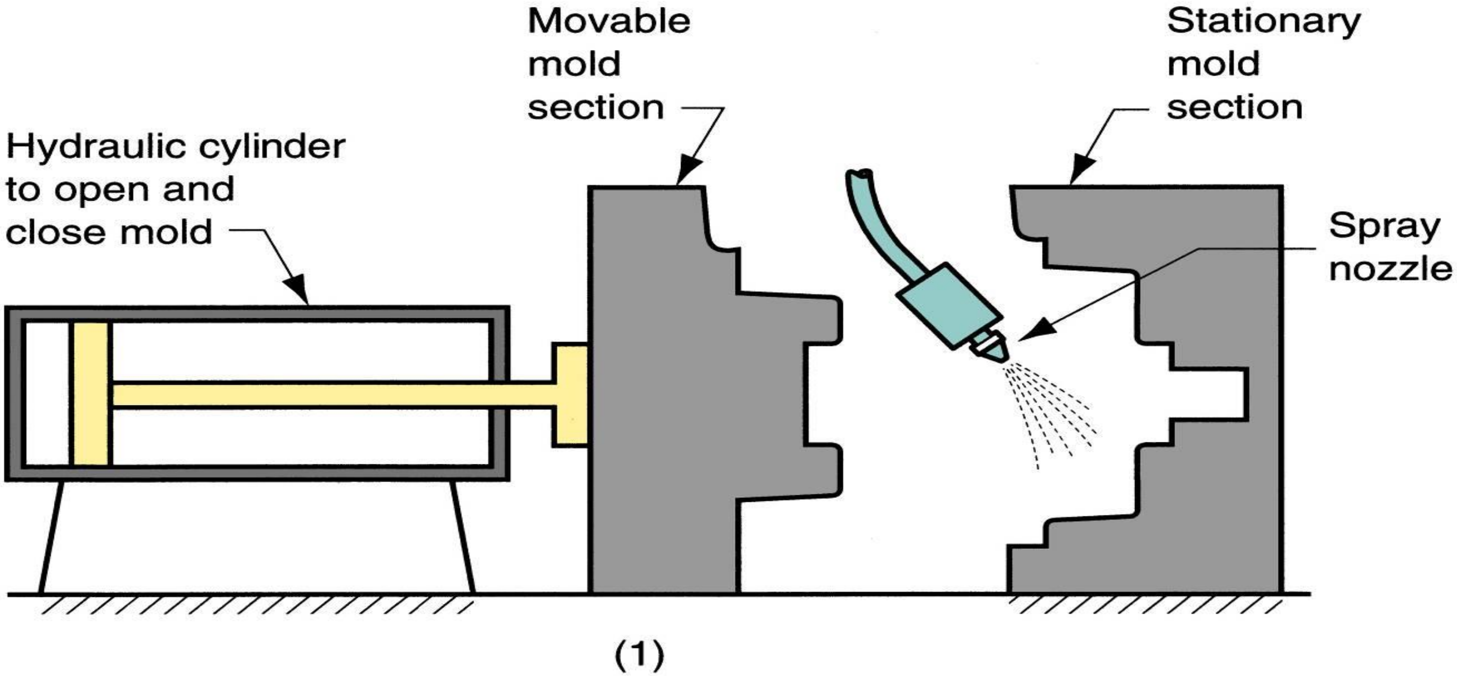


Figure 11.10 Steps in permanent mold casting: (1) mold is preheated and coated

Permanent Mold Casting

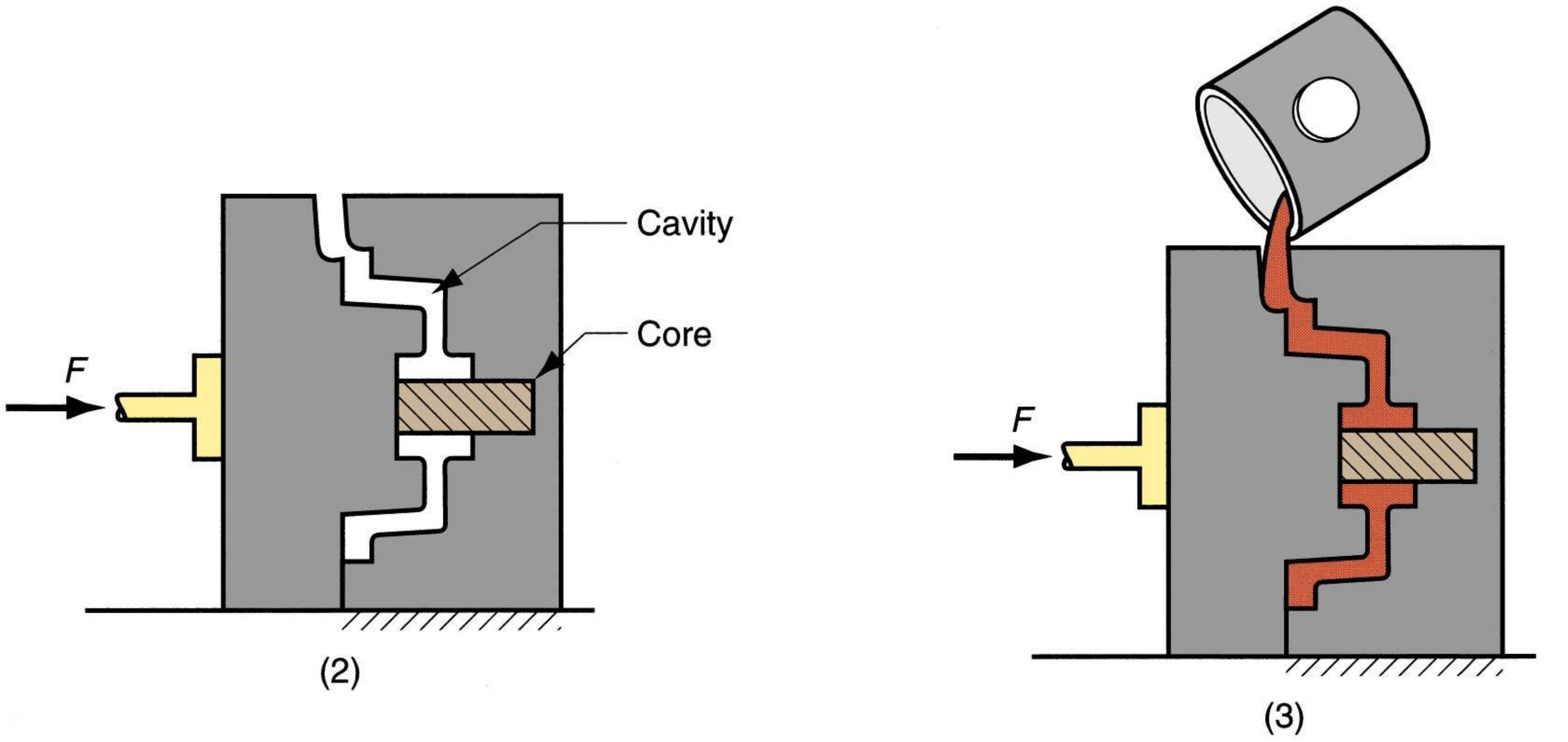


Figure 11.10 Steps in permanent mold casting: (2) cores (if used) are inserted and mold is closed, (3) molten metal is poured into the mold, where it solidifies.

Advantages and Limitations

- Advantages of permanent mold casting:
  - Good dimensional control and surface finish
  - More rapid solidification caused by the cold metal mold results in a finer grain structure, so castings are stronger.
- Limitations:
  - Generally limited to metals of lower melting point
  - Simpler part geometries compared to sand casting because of need to open the mold
  - High cost of mold

Applications of Permanent Mold Casting

- Due to high mold cost, process is best suited to high volume production and can be automated accordingly.
- Typical parts: automotive pistons, pump bodies, and certain castings for aircraft and missiles.
- Metals commonly cast: aluminum, magnesium, copper-base alloys, and cast iron.

Ladles

- Moving molten metal from melting furnace to mold is sometimes done using crucibles.
- More often, transfer is accomplished by *ladles.*

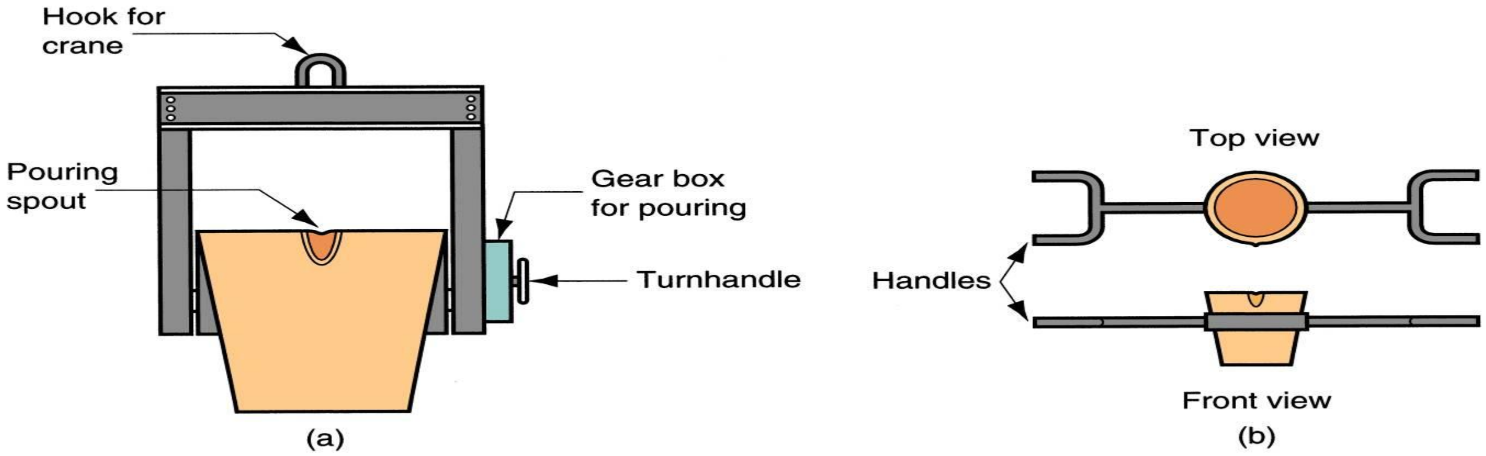


Figure 11.21 Two common types of ladles: (a) crane ladle, and (b) two-man ladle.

Additional Steps After Solidification

- Trimming
- Removing the core
- Surface cleaning
- Inspection
- Repair, if required
- Heat treatment

Trimming

Removal of sprues, runners, risers, parting-line flash, fins, chaplets, and any other excess metal from the cast part .

- For brittle casting alloys and when cross sections are relatively small, appendages can be broken off .
- Otherwise, hammering, shearing, hack-sawing, band-sawing, abrasive wheel cutting, or various torch cutting methods are used.

Removing the Core

If cores have been used, they must be removed

- Most cores are bonded, and they often fall out of casting as the binder deteriorates.
- In some cases, they are removed by shaking casting, either manually or mechanically.
- In rare cases, cores are removed by chemically dissolving bonding agent.
- Solid cores must be hammered or pressed out.

Surface Cleaning

Removal of sand from casting surface and otherwise enhancing appearance of surface .

- Cleaning methods: tumbling, air-blasting with coarse sand grit or metal shot, wire brushing, buffing, and chemical pickling .

- Surface cleaning is most important for sand casting
  - In many permanent mold processes, this step can be avoided
- Defects are possible in casting, and inspection is needed to detect their presence

Heat Treatment

- Castings are often heat treated to enhance properties .

- Reasons for heat treating a casting:
  - For subsequent processing operations such as machining
  - To bring out the desired properties for the application of the part in service

Casting Quality

- There are numerous opportunities for things to go wrong in a casting operation, resulting in quality defects in the product .
- The defects can be classified as follows:
  - General defects common to all casting processes
  - Defects related to sand casting process

General Defects: Misrun

A casting that has solidified before completely filling mold cavity.

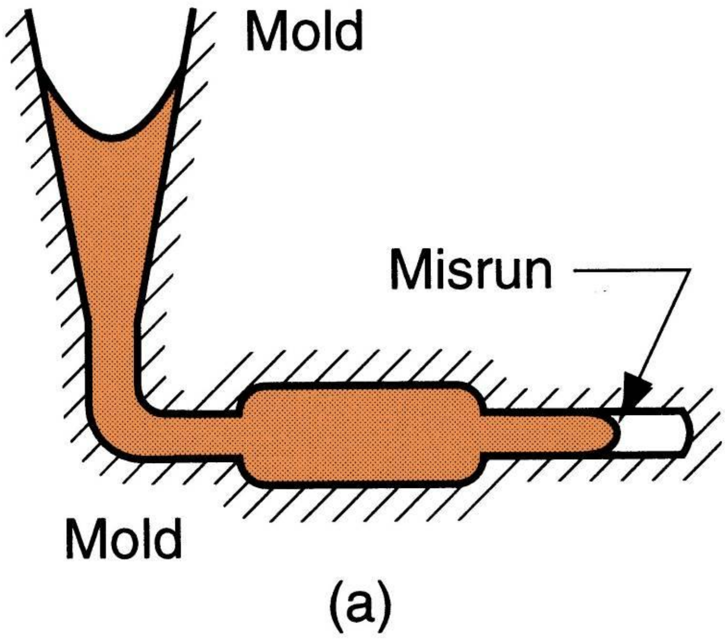


Figure 11.22 Some common defects in castings: (a) misrun

General Defects: Cold Shut

Two portions of metal flow together but there is a lack of fusion due to premature freezing.

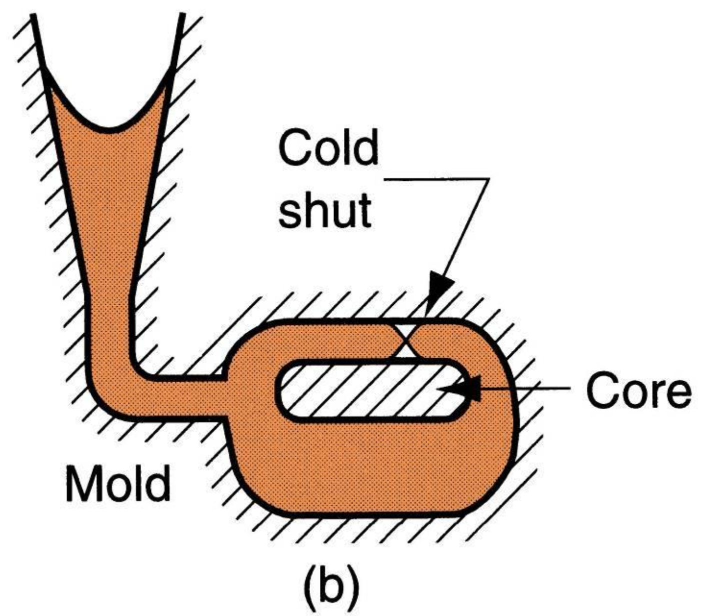


Figure 11.22 Some common defects in castings: (b) cold shut

General Defects: Cold Shot

Metal splatters during pouring and solid globules form and become entrapped in casting

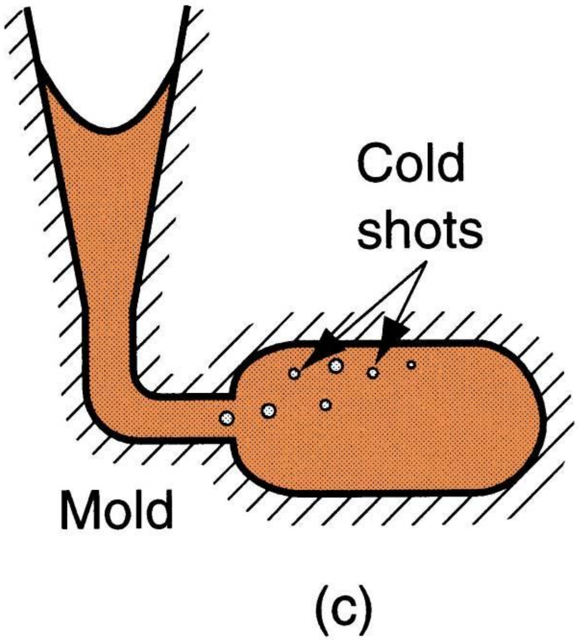


Figure 11.22 Some common defects in castings: (c) cold shot

General Defects: Shrinkage Cavity

Depression in surface or internal void caused by solidification shrinkage that restricts amount of molten metal available in last region to freeze

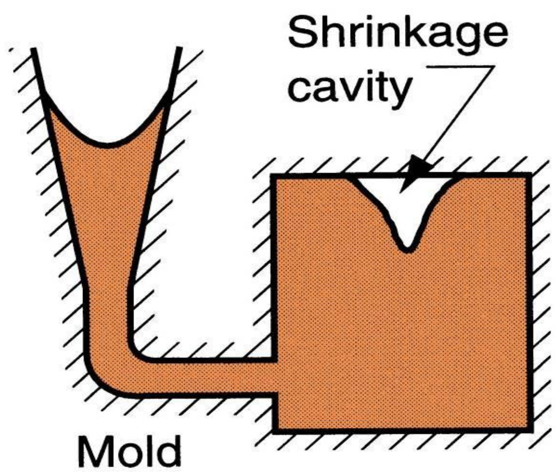


Figure 11.22 Some common defects in castings: (d) shrinkage cavity

Sand Casting Defects: Sand Blow

Balloon-shaped gas cavity caused by release of mold gases during pouring.

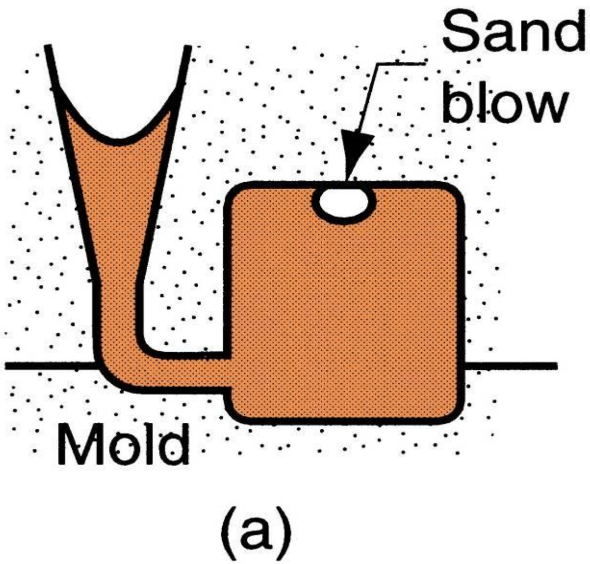


Figure 11.23 Common defects in sand castings: (a) sand blow

Sand Casting Defects: Pin Holes

Formation of many small gas cavities at or slightly below surface of casting.

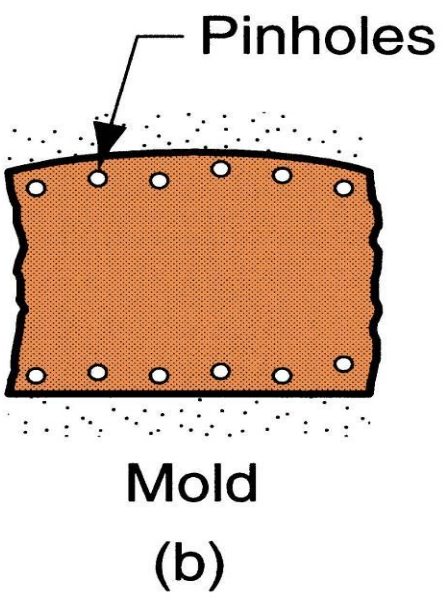


Figure 11.23 Common defects in sand castings: (b) pin holes

Sand Casting Defects: Penetration

When fluidity of liquid metal is high, it may penetrate into sand mold or core, causing casting surface to consist of a mixture of sand grains and metal.

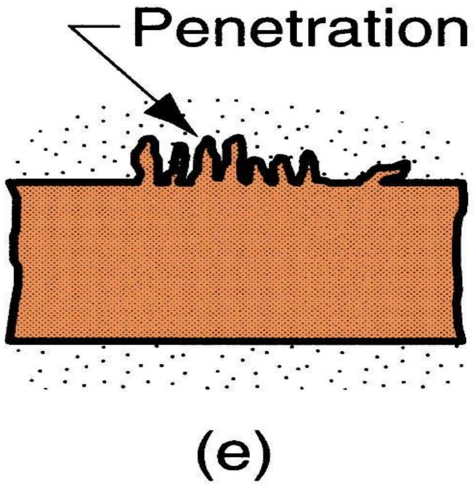


Figure 11.23 Common defects in sand castings: (e) penetration

Sand Casting Defects: Mold Shift

A step in cast product at parting line caused by sidewise relative displacement of cope and drag.

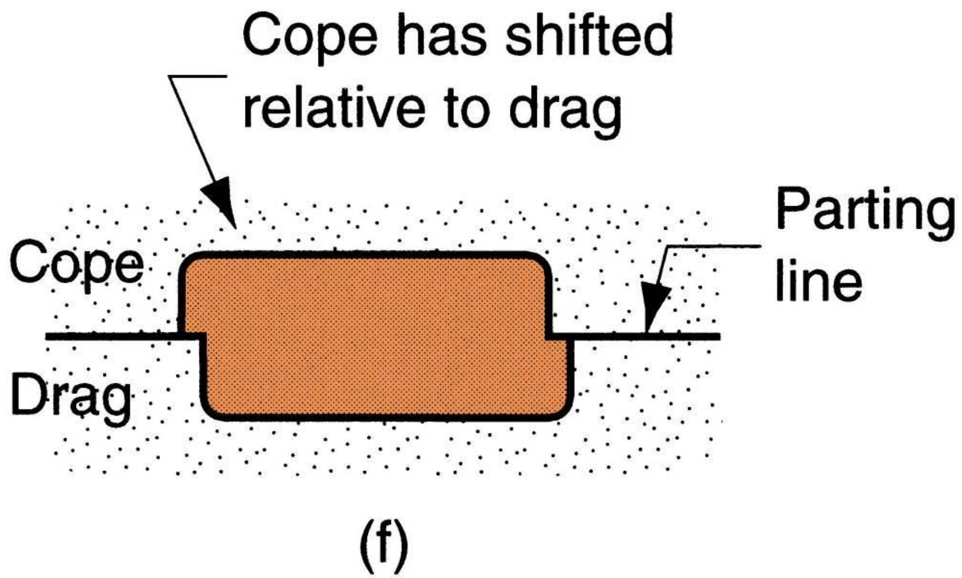


Figure 11.23 Common defects in sand castings: (f) mold shift

Foundry Inspection Methods

- Visual inspection to detect obvious defects such as misruns, cold shuts, and severe surface flaws.
- Dimensional measurements to insure that tolerances have been met.
- Metallurgical, chemical, physical, and other tests concerned with quality of cast metal

Metals for Casting

- Most commercial castings are made of alloys rather than pure metals
  - Alloys are generally easier to cast, and properties of product are better .
- Casting alloys can be classified as:
  - Ferrous
  - Nonferrous

Ferrous Casting Alloys: Cast Iron

- Most important of all casting alloys .
- Tonnage of cast iron castings is several times that of all other metals combined .
- Several types: (1) gray cast iron, (2) nodular iron, (3) white cast iron, (4) malleable iron, and (5) alloy cast irons .
- Typical pouring temperatures ~ 1400°C (2500°F), depending on composition

Ferrous Casting Alloys: Steel

- The mechanical properties of steel make it an attractive engineering material.

- The capability to create complex geometries makes casting an attractive shaping process .

- Difficulties when casting steel:
  - Pouring temperature of steel is higher than for most other casting metals ~ 1650°C (3000°F)
  - At such temperatures, steel readily oxidizes, so molten metal must be isolated from air
  - Molten steel has relatively poor fluidity

Nonferrous Casting Alloys: Aluminum

- Generally considered to be very castable .
- Pouring temperatures low due to low melting temperature of aluminum
  - T_m = 660°C (1220°F)
- Properties:
  - Light weight
  - Range of strength properties by heat treatment
  - Easy to machine

Nonferrous Casting Alloys: Copper Alloys

- Includes bronze, brass, and aluminum bronze
- Properties:
  - Corrosion resistance
  - Attractive appearance
  - Good bearing qualities
- Limitation: high cost of copper
- Applications: pipe fittings, marine propeller blades, pump components, ornamental jewelry

Nonferrous Casting Alloys: Zinc Alloys

- Highly cast able, commonly used in die casting
- Low melting point – melting point of zinc T_m = 419°C (786°F)
- Good fluidity for ease of casting
- Properties:
  - Low creep strength, so castings cannot be subjected to prolonged high stresses

Product Design Considerations

Geometric simplicity:

- Although casting can be used to produce complex part geometries, simplifying the part design usually improves castability .
- Avoiding unnecessary complexities:
  - Simplifies mold-making
  - Reduces the need for cores
  - Improves the strength of the casting

Product Design Considerations

- Corners on the casting:
  - Sharp corners and angles should be avoided, since they are sources of stress concentrations and may cause hot tearing and cracks .
  - Generous fillets should be designed on inside corners and sharp edges should be blended.

Product Design Considerations

- Draft Guidelines:
  - In expendable mold casting, draft facilitates removal of pattern from mold
    - Draft = 1° for sand casting
  - In permanent mold casting, purpose is to aid in removal of the part from the mold
    - Draft = 2° to 3° for permanent mold processes
  - Similar tapers should be allowed if solid cores are used

Draft

- Minor changes in part design can reduce need for coring

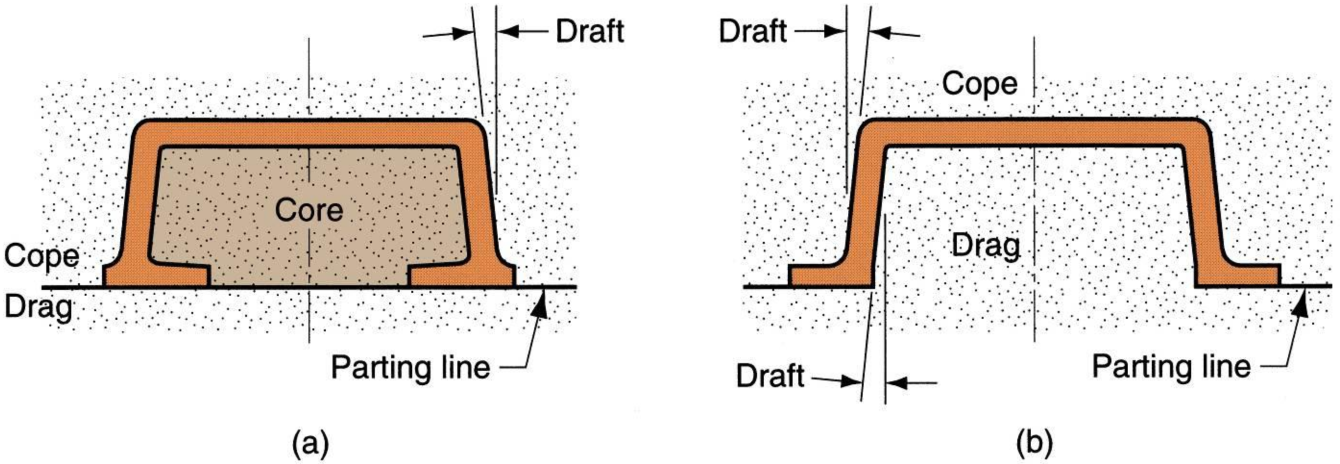


Figure 11.25 Design change to eliminate the need for using a core:

(a) original design, and (b) redesign.

Product Design Considerations

- Dimensional Tolerances and Surface Finish:

Significant differences in dimensional accuracies and finishes can be achieved in castings, depending on process:

  - Poor dimensional accuracies and finish for sand casting
  - Good dimensional accuracies and finish for die casting and investment casting

Product Design Considerations

Machining Allowances:

- Almost all sand castings must be machined to achieve the required dimensions and part features
-
- Additional material, called the *machining allowance*, is left on the casting in those surfaces where machining is necessary.
-
- Typical machining allowances for sand castings are around 1.5 and 3 mm (1/16 and 1/4 in).