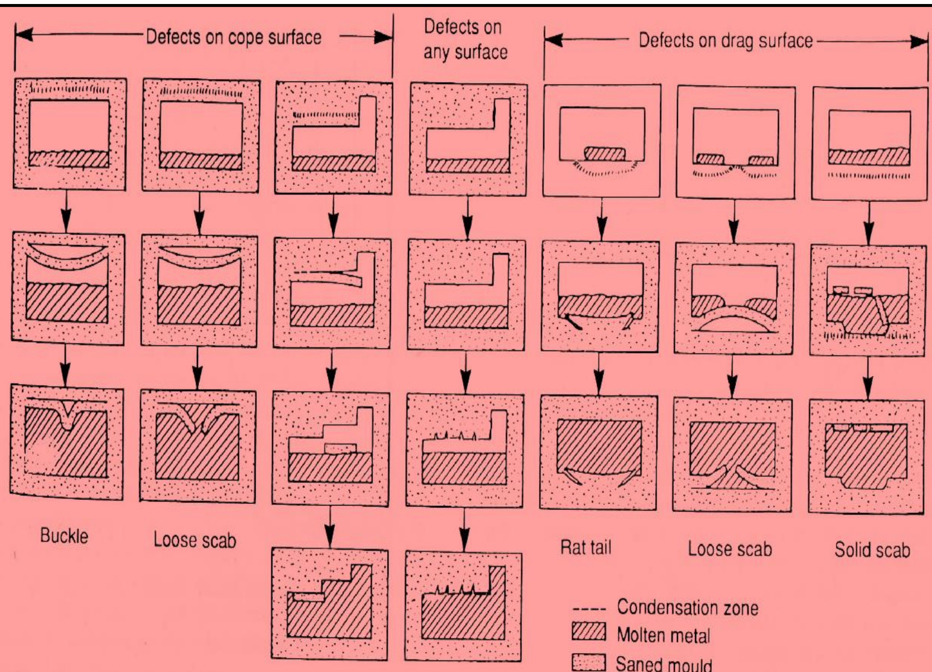


Mould Defects

MME **345**, Lecture **A:05**

Moulding and Casting Methods

3. Sand bonding and moulding defects

Ref:
[1] Heine, Loper & Rosenthal, Principles of Metal Casting, McGraw-Hill, 1976
[2] Beeley, Foundry Technology, Butterworth-Heinemann, 2001
[3] Campbell, Castings, Butterworth-Heinemann, 1991

Topics to discuss today …

1. Introduction
2. Bonding in greensand moulding aggregates
3. Bonding in dry sand system
4. Mould defects

1. Introduction

- Moulding sands for green and dry sand practices are most commonly bonded with clay, the second most important constituent of the aggregate.
- Greensand moulding systems are bonding principally with clay-water systems.
- Synthetic sands are bonded with selected clays from separate deposits and with chemical binders.
- Other common binders are molasses and cement.

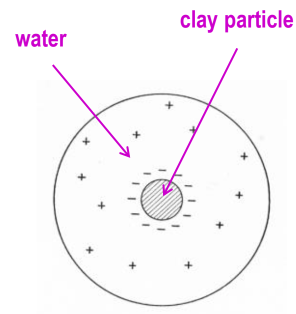
2. Bonding in greensand system

- Bonding between dry clay does not occur;
  bond is developed only when clay particles are hydrated.
- About 4-25% clay and 1.5-8.0% water are commonly used to develop adequate bonding strength.
- Bonding mechanism in clay-water system is not clear.
- Several theories proposed :
  1. **electrostatic bonding**
  2. **bonding due to surface tension forces, and**
  3. **bonding due to inter-particle friction**

2.1 Electrostatic bonding

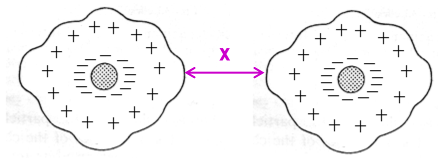
- Bonding between a **network of dipolar forces** operating at the sand-clay and clay-clay interfaces, initiated by the preferential adsorption of positive ions and negative ions on combined water and clay (hydrated) surfaces.
- When water is added to dry clay, the negative hydroxyl (OH^-) ions are adsorbed on the nuclei of the clay atoms, owing to unsatisfied valence bonds at the surface of the clay crystal, and form an integral part of the crystal.
- So the clay-water particle becomes negatively charged.

- The positive (H^+) ions of water are attracted by the negative clay ions, but repelled by the nuclei of the clay atoms, with the result that the positive ions take up equilibrium positions.
- The hydrogen ions and the adsorbed hydroxyl ions about the clay particle comprise a so-called **double diffuse layer**. This formation is called a **micelle**.
- This layer is rigidly attached to the surface of the clay particle and is considered to behave as a solid.

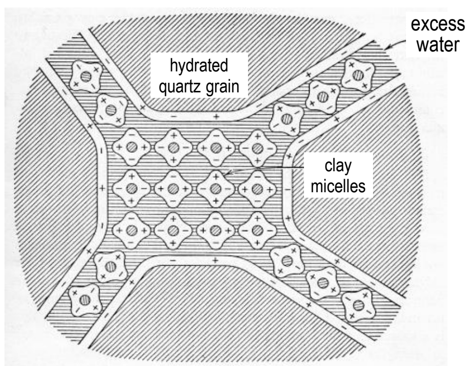


"double diffuse layer" in a clay "micelle"

- Particles of sand (quartz) also form micelles by the adsorption of hydroxyl and hydrogen ions of water.
- When quartz and clay micelles are formed in each other's presence, the hydroxyl ions of the clay micelle exhibit an attraction for the hydrogen ions contained in the quartz micelles.
- Thus **a clay dipole is formed** and the result is an electrostatic bond between sand and clay particles and between clay particles

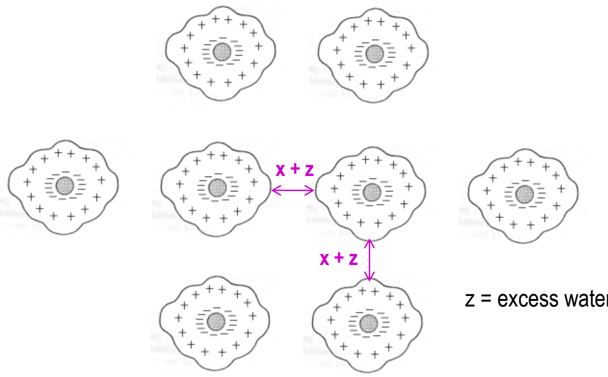


Micellular dipoles, showing the localized concentration of adsorbed negatively charged hydroxyl ions and positively charged ions



Schematic sketch showing disposition of clay and quartz dipoles. In green sand the intermicellular voids are filled with water.

- The maximum attractive force obtained at an optimum distance of intermolecular spacing **x**.
- There are many such dipoles in a clay-water medium.
- Depending on the type of clay, a maximum degree of hydration is necessary to develop a dipole completely.
- This is why the strengths of clay-bonded sands increase with increasing amounts of water, up to a maximum value.



As the amount of water is increased further, water enters the spaces between the dipoles and increases the distance between dipoles greater than x, resulting in a decrease in the net intermicellular force.

2.2 Bonding by surface tension forces

- Bonding resulted due to the **surface tension** of the water surrounding the clay and clay-sand particles.
- Surface layers of water acting on a stretched membrane of hydrated clay, force the particles together.
- When the water layer becomes thinner by drying, the forces holding the particles together increase.

2.3 Bonding due to inter-particle friction

- Bonding resulted following the principles of **block and wedge** theory.
- The inter-particular friction developed between sand particles under pressure .
- Particles are jammed against their neighbours during ramming.
- Opposes further deformation, and causes a bridging action between long rows of favourably oriented particles and the sides of the flask.

3. Bonding in dry sand systems

- Besides using clay, wide varieties of chemical binders are available for making cores and dry sand moulds.
- Chemical binders are mostly based on

  organic resins, sodium silicate, cement, ethyl silicate, and silica sol

- Two common processes:
  1. **As self-hardening mixtures**
  2. **With triggered hardening**

1. As self-hardening mixtures (a.k.a. air-set or cold-setting process)

- sand, binder and a hardening chemical are mixed together
- binder and hardener start to react immediately, but sufficiently slowly to allow the sand to be formed into a mould or core which continues to harden further until strong enough to allow casting
- the process principally used for large moulds for jobbing work

FURANS

Resins (0.8-1.0% of sand) – urea-formaldehyde (UF), phenol-formaldehyde (PF), or UF-PF resins with additions of furfuryl alcohol (FA)

Catalyst (40-60% of catalyst) – phosphoric acid, sulphonic acid

PHENOLIC - ISOCYANATES

Part 1 (0.8%) – phenolic resin in an organic solvent with liquid amine catalyst added

Part 2 (0.5%) – methylene diphenyl diisocyanate (MDI)

2. With triggered hardening

- sand and binder are mixed and blown or rammed into a core box.
- little or no hardening reaction occurs until triggered by applying heat or a catalyst gas; hardening then takes place in seconds.
- the process is used for mass production of cores and, in some cases, for moulds for smaller castings.

Heat-triggered processes

- The sand and binder are mixed then introduced into a heated core box or pattern. The heat activates the catalyst present in the binder system and cures the binder.
- Common heat-triggered processes are: phenolic novalac resin based **Croning process**, PF-UF or UF-FA based **hot box process**, and furfuryl alcohol based **warm box process**.

Gas-triggered systems

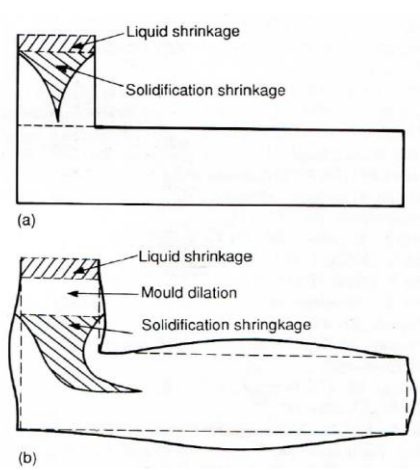
- Sand and binder are mixed and blown into a core box then a reactive gas is blown into the core box causing hardening of the binder. Hardening occurs at room temperature.
- Examples: **sodium silicate – CO_2 process** and phenolic-isocyanate-amin vapour based **cold box process**.

4. Mould defects

- When the molten metal enters the mould, the mould reacts violently.
- Frenzied activity crowds into this brief moment of the birth of the casting: buckling, outgassing, pressurization, cracking, explosions, disintegration and chemical attack.
- The survival of a saleable casting is only guaranteed by the strenuous efforts of the casting engineer to ensure that the moulding and casting processes are appropriate, and are under control.
- The most common moulding defects to consider are:
  (1) mould shape and size change, and
  (2) metal penetration

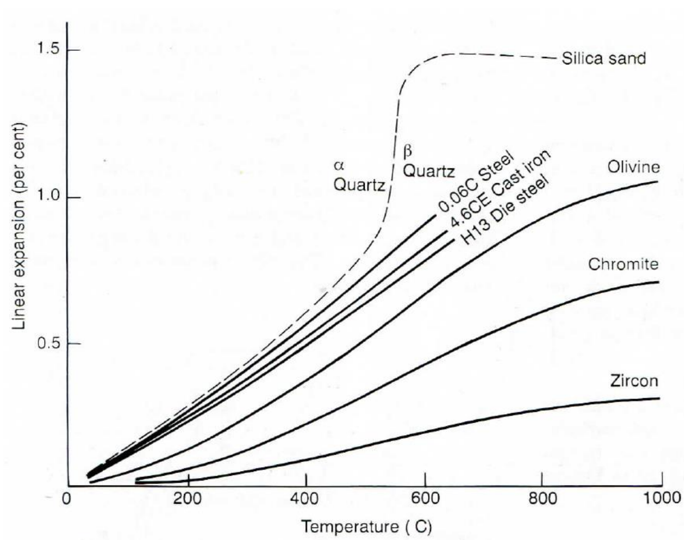
3.1 Mould shape and size change

- The change in shape of the mould as metal enters is one of the most important defects.
- Any expansion of mould (a.k.a. mould dilation) results an increased demand for feed metal.
- If the feeder size has not allowed for this effect, shrinkage pipe will extend into the casting, making the casting unsound.
- Although causes to affect dimensional tolerance, mould wall movement may be helpful to reduce hot tearing.

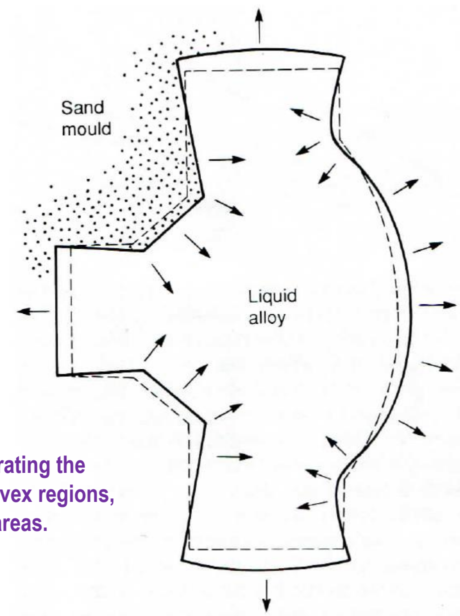


A comparison between (a) a rigid mould and (b) a weak mould in the effect on external size and internal porosity of the casting.

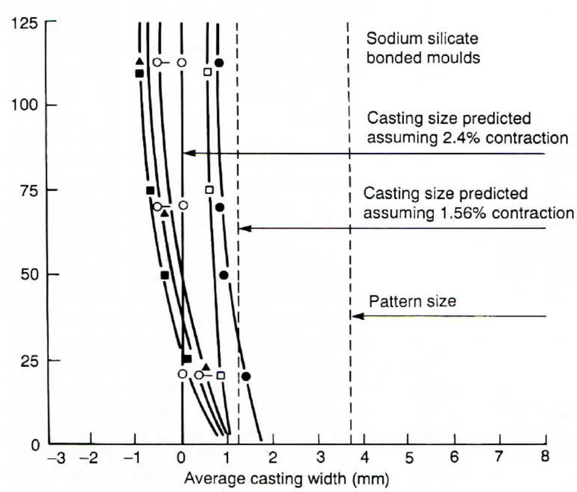
- Common causes for mould shape and size change are:
  - (1) Mould hardness and moisture content
  - (2) Thermal expansion of mould
  - (3) Heat content of liquid metal
  - (4) Pressure from the melt and mould/core gas
  - (5) Pressure due to casting expansion on solidification



Temperature-expansion curves for various mould materials



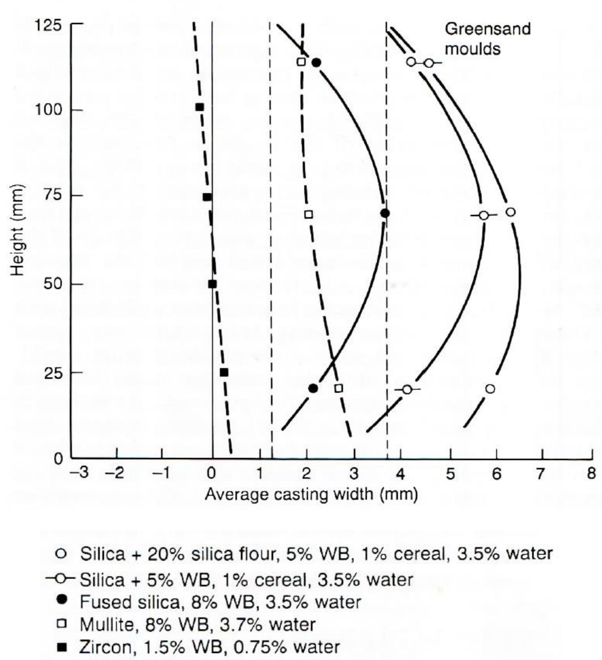
The movement of mould walls, illustrating the principle of inward expansion in convex regions, and outward expansion in concave areas.



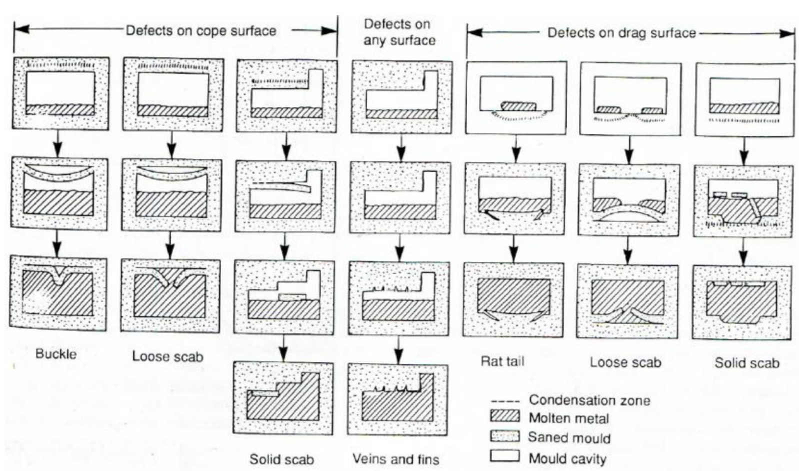
○ Silica + CO_2 gassed + basic mix
○– Silica + 2% Si + basic mix
● Fused silica + 2% Si + basic mix
▲ Alumina + 2% Si + basic mix - 2% alumina
□ Olivine, 3% kaolin, 2% Si, 3.3% sodium silicate
■ Zircon, 2% kaolin, 1% Si, 2% sodium silicate

Basic mix = 2% Organic 1.7% Fireclay 2% Alumina (–325 mesh)

The shape of the sides of a 150-mm-sided cube casting in steel, cast in rigid sands



The shape of the sides of a 150-mm-sided cube casting in steel, cast in various greensand mixes.



a selection of mould surface defects due to thermal expansion and failure of mould surface

Common causes:

(1) Thermal expansion due to α/β transformation at 550 °C, and **(2)** Condensation of water

Common remedies:

(1) Increase sand strength (increased clay, reduced water, fibre reinforcement), **(2)** Increase rate of casting, **(3)** Provide radiation barrier (by using coal dust), **(4)** Reduce casting temperature, **(5)** Mould venting.

3.2 Metal penetration

- When pressure of liquid metal is sufficiently high, surface tension no longer able to resist metal penetration into the spaces of sand grains of the mould, resulting **metal penetration** defects.

- Affected by:
  (1) sand fineness
  (2) gas and liquid metal pressure
  (3) wettability of mould

- Methods to overcome metal penetration:
  (1) use of finer sand/particle of high refractoriness (zircon, graphite, etc.)
  (2) use of mould wash or mould coat
  (finer sand/particle in a carrier liquid, e.g., alcohol or water)

Next Class
MME **345**, Lecture **A:06**

General Methods of Moulding Casting

4. Sand testing and quality control