Rotary kiln

The rotary kiln is an essential part of the cement production process, where it transforms raw materials into clinker through heat and chemical reactions, making it a vital component of cement manufacturing.

Its structure consists of a steel cylinder lined with refractory bricks, which are essential for withstanding the extreme temperatures inside the kiln.

The kiln is typically inclined at an angle ranging from 0.5 to 0.75 degrees from the horizontal axis. This slight incline helps facilitate the movement of raw materials along the length of the kiln as it rotates. The rotary kiln usually operates at a speed of 0.5 to 1 rpm, which ensures a thorough and uniform processing of the materials.

During operation, the raw materials, in the form of powder or slurry, enter the kiln and progress through various heating zones. The combination of the kiln's slow rotation and incline ensures even heating of the materials, promoting the chemical reactions necessary for the formation of clinker.

The high temperatures, typically between 1400°C and 1500°C, enable the decomposition of calcium carbonate and the formation of essential compounds such as calcium silicates, which are critical for cement production.

It is divided into four distinct heating zones, each serving a specific purpose in the cement production process (**fig ?**).

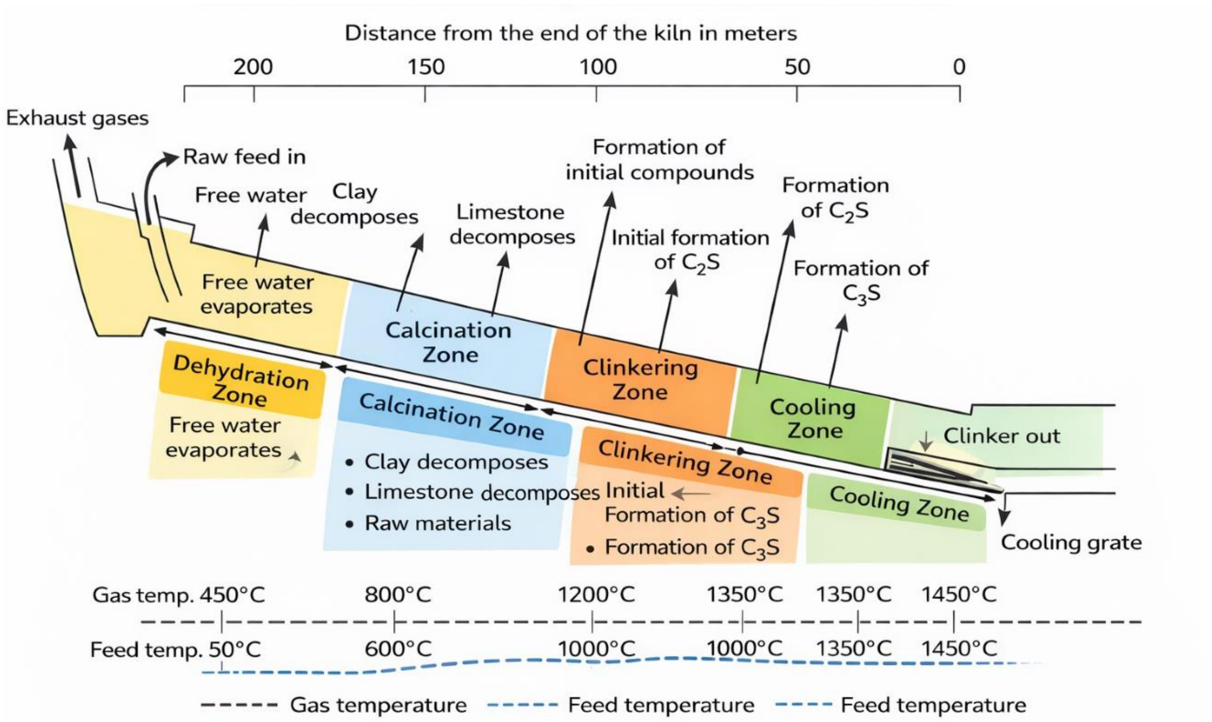

Figure . Processes inside a rotary kiln for cement production

1. **Drying Zone**

In this initial zone, the raw materials are heated to remove moisture. The temperature gradually increases, and the raw materials start to dry out as they move through the kiln.

2. **Calcination Zone**

This is the zone where **calcium carbonate ($CaCO_3$)** begins to decompose into calcium oxide (CaO) and carbon dioxide (CO_2). The calcination process is essential for the transformation of the raw materials into more reactive compounds that will later form cement.

3. **Burning or Clinkering Zone**

The most critical zone, where the highest temperatures (around 1400-1500°C) are reached. The chemical reactions that produce the main compounds of cement, such as **calcium silicates**, occur here. The raw materials react to form **clinker**, the intermediate product that is then cooled and ground into cement.

4. **Cooling Zone**

After the clinker is formed, it moves into the cooling zone, where it is rapidly cooled to stabilize the compounds. This step is vital to prevent further chemical reactions and to preserve the desired structure of the clinker.

Reaction of clinkering zone

Several important chemical reactions take place that influence the properties and quality of the cement. These reactions contribute to the final strength and setting of the cement.

Formation of tetra calcium aluminate ferrite (C_4AF),

$4CaO + Al_2O_3 + Fe_2O_3 \longrightarrow 4CaO.Al_2O_3.Fe_2O_3$. Responsible of sea water resistance.

Formation of **tricalcium aluminate (C_3A)**,

$3CaO + Al_2O_3 \longrightarrow 3CaO.\ Al_2O_3$. Responsible for the setting.

Formation of **dicalcium silicate (C_2S)**,

$2CaO + SiO_2 \longrightarrow 2CaO.\ SiO_2$. Responsible of the final strength.

Formation of the **tricalcium silicate (C_3S)**

$2CaO{\cdot}SiO_2 + CaO \longrightarrow 3CaO{\cdot}SiO_2$. Responsible of the initial strength.

General idea of Cement examples

Clinker Sample

مفتاح المسألة

- Fe_2O_3 (3.1%) → C4AF
- Al_2O_3 (4.5%) → C4AF
  → C3A
- CaO (64.5%) → C4AF
  → C3A
  → C2S
  → C3S
- SiO_2 (23.4%) → C2S

Cement Sample

- Fe_2O_3 (3.1%) → C4AF
- Al_2O_3 (4.5%) → C4AF
  → C3A
- CaO (64.5%) → C4AF
  → C3A
  → C2S
  → C3S
  → Gypsum
- SiO_2 (23.4%) → C2S
- SO_3 (2.3%) → Gypsum