Rotary Kilns – Processing Equipment for the Heat Treatment of Bulk Solids
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Rotary kilns are frequently used for the thermal treatment of bulk solids used in daily life. Their applications extend from chemical and pharmaceutical products, such as pills and pigments, building materials, such as cement, mining and smelting materials, such as ores, coal and coke, to catalyst substrates, abrasives and battery materials. In each case the heat treatment process must be adapted to the respective type of bulk solids. Today, in addition to a wide range of different industrial furnaces, principally rotary kilns are used [1–3].

General
The key feature of rotary kilns is that during heat treatment the bulk solids are constantly moved through the kiln from the feed to the discharge end as a result of the rotation of the slightly inclined tube. The kilns are generally operated continuously and fully automatically. They allow direct transport of the bulk solids without further conveying equipment, which makes these kilns very energy-efficient [4].

As the rotary kiln process has a significant mechanical impact on the bulk solids, rotary kilns must be specifically designed for the materials treated in them. As parameters characterizing the bulk solids behaviour, their flow behaviour, flowability, bulk density, moisture content and process temperature have to be taken into consideration and provision made for these in the design and engineering of the heat treatment equipment. Adaption to the specific bulk material is effected by variation of the inclination of the tube along its length, the rotary speed of the tube and, if required, additional components installed inside the tube.

In the ceramics, glass and binder industries, rotary kilns are used today for the thermal treatment of powder, granular, lumpy and dry or wet mixes. The main applications are drying, debinding, presintering, calcining, foaming and sintering.

In the following, key rotary tube kiln processes are presented with reference to typical applications for different atmospheres. A basic differentiation is made depending on the type of heating between directly heated rotary kilns (Fig. 1), and indirectly heated rotary kilns (Fig. 2).

Indirectly heated rotary kilns
In indirectly heated rotary kilns, the rotary tube is heated from outside. This can be effected by means of burners or electric heating. The indirectly heated model is used especially when the treated product is prone to strong dust formation, has to go through a defined temperature profile or has to be treated in special process conditions, e.g. inert or protective atmosphere.

As tube materials, depending on the process requirements with regard to maximum temperature, atmosphere and bulk solids properties, metal tubes are used up to 1150 °C. Ceramic rotary tubes are used to protect the product against contamination and permit much higher temperatures (up to 1600 °C) than metal tubes. However, ceramic tubes are limited with regard to their geometry in manufacturing. This also applies to the application of tubes made of graphite.

Fig. 3 shows the 3D model of a DRA rotary kiln. The actual rotary tube is supported on rollers by means of two riding rings. It is driven by means of a friction wheel or gear ring/chain. The product is fed from the left by means of an infeed screw conveyor or vibrofeeder.

The tube is sealed at both ends by means of mechanical axial seals, which seal off the kiln chamber atmosphere in the tube (product chamber) against ambient air.
processes in the rotary tube, for example, lifters, which ensure cascading of the material. Additional baffle rings, for example, are used at the kiln exit to increase the filling level of the easy-flowing bulk solids in the kiln. The heating equipment is installed in an insulated casing surrounding the rotary tube. Heating is effected by means of burners, which, corresponding to process requirements, are divided into several control groups over the tube length and flush the rotary tube with flue gases to obtain specific temperature profiles [4].

The use of recuperator burners is an option for indirectly heated rotary kilns to selectively use the energy of the flue gases for preheating the combustion air at the burners. Riedhammer can install the RKO burners developed within the SACMI Group and therefore offer a very economic and highly energy-efficient alternative to the burners established on the market. After the heat treatment in the heated rotary tube, generally a cooling process follows to cool the product to approximately room temperature.

Fig. 3 shows a rotary kiln in which the directly heated rotary tube is connected with the cooling tube by means of a chute. Here, the direction of product transport is from right to left here. Such a kiln concept is used especially when condensation on cold surfaces must be avoided during the heat treatment process. In multistage rotary kiln processes as generally applied in material recycling or pyrolysis processes, the kiln atmosphere contains high loads of highly and medium bituminous volatile constituents. To reliably avoid condensation, the insulated kiln feed and discharge cars are additionally heated. Moreover, the product is fed and discharged via lock systems to reliably prevent the ingress of air into the tube and avoid entrainment of the process gases into the cooling zone with the risk of condensation. In addition it is important to seal the rotary tube against leakages so that often the feeding and discharging equipment is designed to be gastight in these applications. Another model of kiln is the directly heated rotary kiln.

Directly heated rotary kilns

Directly heated rotary kilns are heated with a burner firing directly into the rotary tube. For this reason, this type of kiln is termed an internally heated rotary kiln or DRI. Directly heated rotary tubes generally consist of insulated kiln feed and discharge cars and a rotary tube generally lined with refractory insulation. The insulation serves primarily as thermal protection, must, however, be designed far more as wear protection or as an inert protective layer between tube and bulk solids [4]. Rotary kilns of this type are heated directly with a burner at the front. Generally, the burner gases and flue gases are led in the opposite direction to the transport of the products.

Fig. 4 shows a schematic of the structure of a directly heated rotary kiln. The material is fed from the left by a feeder in the feed car. At the other end is the burner in the discharge car. The flue gases flow towards the product coming along the length of the inclined rotary tube. Accessed via a shaft with chute, the cooling tube is arranged under the discharge car. Directly heated rotary tubes are also used when, for example, the product is fed as slip or slurry. In this case, as shown here, a predryer is installed upstream of the rotary tube with refractory
A specific temperature curve can be set over the kiln length [2]. Fig. 8 shows a comparison of the temperature profile with associated dwell time at maximum temperature for a directly heated rotary kiln and a corresponding pendulum kiln. In the directly heated rotary kilns, firing chamber and heat treatment chamber form one unit, and the process temperature profile is essentially determined by the selected burner configuration and the form of the burner flame. In the pendulum kiln, this is not the case, the process temperature profile is, as in the indirectly heated rotary kiln, selectively determined by means of individual heating groups, as a result of which a specific temperature plateau can be realized.

**Summary**

For the heat treatment of bulk solids, directly and indirectly heated rotary kilns are available, the process engineering of which can be adapted to the complex bulk solids properties, such as flow behaviour, flowability and the mechanical properties of the bulk solids.

![Diagram 1](image1)

**Fig. 6** Directly heated DRI rotary kiln with flange-mounted predrier and separate cooling tube (Schematic: Riedhammer GmbH)

![Diagram 2](image2)

**Fig. 8** Dwell time versus temperature in rotary and pendulum kilns (Schematic: Riedhammer GmbH)
Rotary kilns are robust production plants with high throughput rates, which permit selective adjustment of temperature and dwell time and, in gastight design, selective control of the atmosphere. Rotary kilns are very energy-efficient as no additional transport aids, like setters, or handling equipment are necessary, they enable excellent heat transfer, and very short dwell times.

In ceramics, rotary kiln technology has repeatedly proven itself as a starting technology for new and innovative applications and products. Finally, key features of rotary kilns are maximized availability, minimized space and labour requirement and excellent cost efficiency.

References