White Paper:

High Temperature Powder Processing - Advancements in Rotary Furnace Designs

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Rotary furnaces are the go-to technology for high temperature processing of powdered materials. They inherently offer significant advantages of throughput and energy efficiency over other forms of continuous, high temperature equipment. Some materials are well served by simple tube designs. In other cases, reaction conditions or stringent time-at-temperature requirements may necessitate more advanced designs. In this discussion we will review several indirect-fired rotary furnace design improvements that are targeted to maximize the utility of the process while meeting the critical needs of more difficult processes.

Mixing & Conveying Technologies

Riffle-flights (Figure 1) for rotary furnaces are axial mixers. Normally, axial mixing in a rotary is not desired. However, the following are examples where it provides an improvement to the processing environment in a rotary furnace:

1. Exothermic Reaction: If the process is operating near an unstable point, the traditional approach is to increase the heat transfer area (length and diameter) of the furnace to move away from the unstable operating conditions. Riffle flights allow the reaction energy to be absorbed into the cold feed material. This reduces the energy requirement overall and reduces the CAPEX by optimizing on a smaller equipment size.

2. Batch, Gas-Solid Reaction near Stoichiometry: A rotating reactor containing solids that are reacting with an axially flowing stoichiometric gas would produce different grades of material at different positions along the length of the reactor. Riffle flights continuously distribute the material randomly along the reactor axis. All particles of the solid spend approximately equal times at the different positions along the reactor creating a uniform product.

3. Mixture with Reactive Solid Addition: Riffle flights can be used to make a continuous in-line mixer at the threshold of the reactor. This minimizes stored volume of the mixed reactive solid. This helps to minimize excess addition while maintaining a complete reaction.

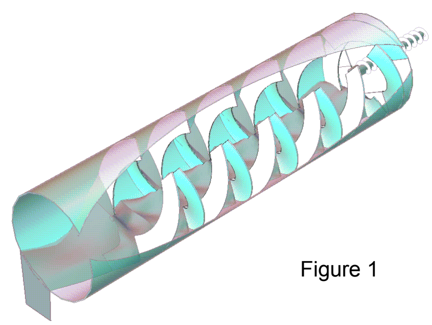

Figure 1

Helical flight technology is another alternative. It is limited to relatively short residence times, as the material is conveyed through the furnace at a uniform rate. The drawback of this technology is that it is difficult to employ when you have a long residence time, but beneficial for reactions with a narrow time-at-temperature requirement.

Atmosphere Management

Multiple atmospheres can be achieved through design of independent, but cascading rotary systems with atmosphere isolation. Control of pressure between upper and lower units is critical to ensure complete separation of the atmospheres. The design in Figure 2 utilizes stacking rotaries to take advantage of height opportunities and eliminates need for material conveyance equipment by utilizing gravity. This custom system enables long residence times, multiple atmospheres and high production volumes.

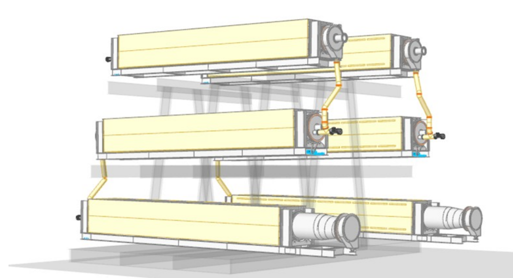

Figure 2

Another unique rotary furnace design may include advanced control of multiple atmospheres in a single tube. This is advantageous as it eliminates the need for multiple unit operations and condenses the requirements into one. In such a design, some of the atmospheres are created from volatiles generated from the product, like water, VOCs or metal vapors.

Ultra High Temperature Processing

The ultra high temperature system in Figure 3 is designed for atmosphere sealing of both for the process atmosphere and the chamber atmosphere, which allows the use of specialty tube materials such as graphite or refractory metals. These are required for very high temperature processing, typically temperatures well over 2000°C. A key challenge is the clamping and driving of the tube, especially when it is contained within the chamber atmosphere. This often precludes the ability to maintain the seal without temporarily stopping production. In this schematic, the tube holding and driving method is located external to the chamber atmosphere. It allows for tube expansion and expansion mismatch at the ends of the tube. It is driven on both ends to minimize torque transmission through the tube.

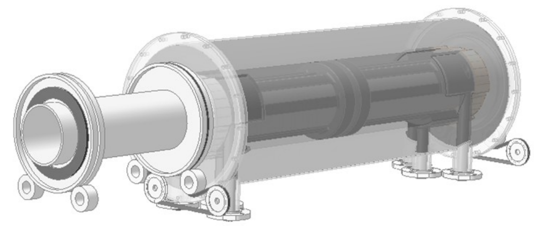

Figure 3

The style of holding the tube shown also provides a space for water-cooling. The same tube support length can be surrounded by a water-cooling spray. Cooling at both ends is critical for processing at these temperatures, as compared to a traditional alloy rotary which may only have a cooling section at the discharge end to cool the product. This style keeps everything cool; drive system, riding tires, gaskets, feeding equipment, discharge valves, and the product.

High Production Volume

After initial materials development investigations and pilot scale production campaigns, it is necessary to consider commercial scale production. Scaling of thermal processes is rarely a simple matter of linear extrapolation. At experimental scale, the conversion rate of many solid-solid and solid-gas reactions is primarily a function of the set point temperature, overall atmospheric chemistry, size of the reactants, and the quality of the inter-mixing. In small research test furnaces, the furnace temperature can track the control profile very well. If the sample load is relatively small, it may also track well with this desired profile. At the same time, the ability to remove product gases and replenish with fresh gas is simplified by the small internal volume of the furnace, and ratio of sample to furnace volume. Under these experimental conditions, product uniformity is rarely a significant concern.

As the reaction is scaled to larger sizes, the ability to heat or cool the mass of material and the ability to introduce or remove gasses from the solids plays an increasingly important role in reaction efficiency. Often these become the primary variables that control the conversion rate, and therefore the throughput and efficiency of the process. These variables create process limitations that extend the total processing time, which impacts both throughput and total energy utilization of the process.

Harper's expertise in process scale up allow for designs accommodate mass rates from tens to thousands of pounds per hour. Figure 2 offers a contained processing environment around 1,800 ft³ with multi-atmosphere, long residence time system. Figure 4 is designed for a traditional residence time at high production rates. Often, large indirect, rotary tubes with high mass throughputs can be limited in production or useful life due to large stress in a section of the tube. This can be mitigated using internal tube features to properly pre-treat or add time to the first heat up zone. This is where the majority of the tube stress builds up, typically because of feed moisture or low boiling organics. Managing these volatiles and segregating atmospheres along the length can also increase production rate. The removal of volatiles drives reactions and can minimize certain sticking phenomena. In turn this allows for higher throughput and utilization of the large process volume.

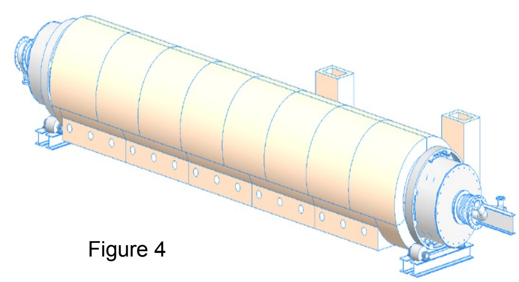

Figure 4

Conclusion

Ultimately, the ideal future design state equally incorporates improvements in product quality, throughput, energy efficiency and operating expenses. More complex chemical reactions will require thoughtful consideration of the kinds of design enhancements reviewed here to ensure the best balance of all the critical factors.