White Paper:

Thermal Processing Optimization: Using Advanced Rotary Tube Internals to Achieve Operational Improvements

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Introduction

Thermal process of powders (including calcination, sintering, carburization, etc.) is dominantly performed, due to its inherent characteristics, in rotary tube furnace. Rotary furnaces are known to be the preferred processing unit for flowable powdered or granular materials. The rotary tube furnace, under the proper conditions, will be significantly more energy efficient than the pusher tunnel furnace. The energy requirement of heating the rigid furniture of the pusher tunnel furnace is replaced by the stationary but rotating tube of the rotary, which sets the rotary apart with significant lower total energy consumption.

But what is less widely known about the rotary, and what will be discussed, is a rotary's capability of becoming even more energy efficient with the use of tube internals. The use of tube internals in a rotary furnace can increase heat transfer surface area, improve radial mixing, improve gas-solid interactions, control gas flow direction, and even control material dwell time or velocity through the tube. All of these can result in a reduction of residence time required or increase unit capacity for a given volume of furnace but can also improve product quality and control of quality and uniformity.

Surface Area

At its most elementary function, a tube internal for a rotary furnace will increase the surface area for heat transfer. Through its mere presence in the heating section of the rotary furnace the internals will be maintained at temperature (a lower temperature than the tube wall but higher than the process material, thermal conductivity of steel vs. bulk material) and in turn provide another surface, other than the inner wall of the process tube, to transfer heat to the product. This increased heat transfer area can be thought of as the fins or plates of a heat exchanger; an increase in the fins or plates of a heat exchanger will increase the total heat transfer of the exchanger.

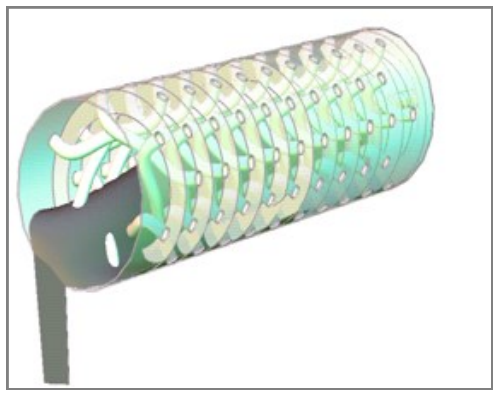

Figure 1: Cooling Tubes

When considered in the preliminary designs of the rotary furnace, the added heat transfer surface area can reduce the required total processing length of the rotary furnace. If the intention is to add internals to an existing rotary furnace it is conceivable that the added heat transfer surface area may reduce the required residence time for processing which will in turn increase the mass throughput capabilities of the unit.

Increasing more surface area does not just aid in the heating of the process material but can also aid in cooling the product post processing. Many rotary tube cooling chamber do not contain internals in the overall design, they are typically a simple water cooled jacket around the outside of the rotary tube, but this is not always efficient. By introducing more surface area inside the tube, the material will see more cold surfaces and cool more efficiently. Some designs not only utilize the increased surface area of a tube internal, conducting heat just through the tube wall, but also allow the cooling water to flow inside the internals yet again increasing the total cooling efficiency (see Fig. 1). In this design, the pipes running through the process area are open to the outside of the tube such that cooling water and flow through without wetting the process material, thus allowing for an increase in cooling surface without relying solely on the heat transfer through conduction with the rotary tube wall.

Radial Mixing

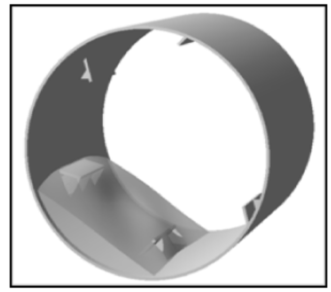

Figure 2: Radial Mixing Flight

Product homogeneity and consistency is vital for all high value advanced materials. When processing in a rotary furnace with specific tube internals, such as flat bar lifters (see Fig. 2), consistency can be greatly improved by increasing the radial mixing of the material. The flat bar lifter, when sized below the height of the bed of material, will cause agitation in the bed of material as it is conveyed by the rotary tube and increase envelopment. If the lifter was to be sized larger than the bed of material a greater bed turn-over is achieved, but this may come at a cost. A greater chance of reduced yields of material due to entrainment and dusting can occur if the material particle size is too small and the processing gas velocity is too high.

Improved Gas-Solid Interaction

Reaction gas is vital for many of the processes, such as aluminum nitriding and boron nitriding. The need for consistent contact of the material bed with the reaction gas will determine whether or not the reaction takes place. Knowing this, it is not always necessary to reduce the tube fill percent in order to insure gas penetration through the entire bed to obtain the needed gas-solid reaction. The addition of uniquely designed lifters in the rotary furnace can bring material up along the tube walls to a curtain point of discharge where the material is dropped through the process gas, thus, increasing the time exposure and amount of material exposed to the process gas.

Controlled Gas Flow

Contact of the process off-gas(es) with the final product, depending of the reaction, can hinder product quality. This is common when off-gassing moisture and trying to prevent the vapor from condensing on the dry reacted product. In some cases, off-gas contact with the raw feed material can also hinder processing. If this is an issue, strategic placement of a solid core helical flight or Archimedes screw may be the solution. The helical flight or Archimedes screw can create enough of a barrier preventing unfavorable gas migration.

Material Flow

A rotary furnace is not only a great piece of thermal equipment for powder processing, but also for large agglomerates or irregularly shaped materials. Without internal flights in the rotary tube these irregularly shaped materials and agglomerates may segregate themselves due to the tumbling flow through the tube. This phenomenal can be controlled with the use of an Archimedes screw that is continuous throughout the entire tube length. In this case, the rotary tube angle does not play as large of a role in determining the residence time of the material but rather the pitch of the flight paired with the tube rotation will determine the exact residence time. In many cases, when processing in the rotary, a short section of a helical flight is installed at the entrance of the tube. This is done to ensure that material does not build up at the entrance causing the material to spill forward into the entrance chamber or worse, cause material to plug up the tube.

Current Processing

As an industry leader in custom thermal processing equipment, Harper International has recently paired up with U.S. Demil, LLC. in a successful effort to design a rotary tube furnace utilized in the demilitarization of excess, obsolete and unserviceable munitions, done so for safety and environmental purposes. One of the key features that made this project successful was the specific design for tube internals. This particular design had to take considerations for the controlled migration of material through the tube while acting as a containment preventing chain reactions due to rapid exothermic reactions, controlling gas flow through the reaction area and most significantly forcing a specified key reaction location within the rotary tube. Functional tube internals can improve processing efficiency and product quality, but may make the difference between success and failure.

Examples of Tube Internal Designs

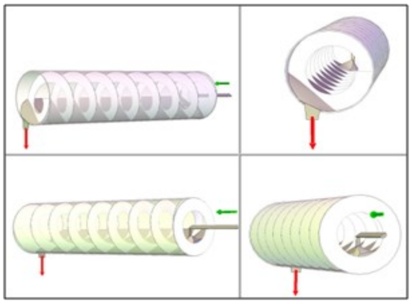

Figure 3: Continuous Helical Flight

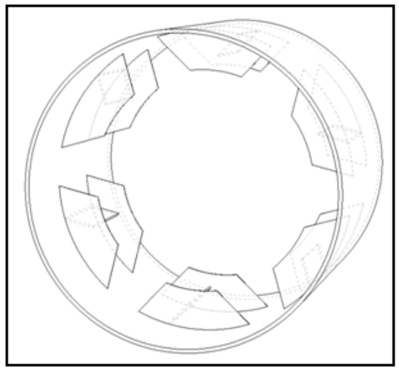

Figure 4: Non-Mixing Flat Lifter Flights

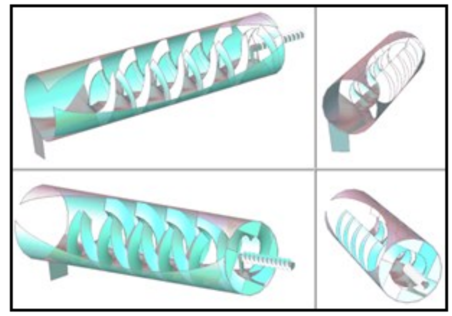

Figure 5: Axial Mixing Flights