**Sintering of small oxide ceramic components**

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In 1997 Entech received an order to develop and construct something totally new. One of our customers had a demand for a continuous high temperature furnace for the sintering of small alumina and zirconia components. It had to reach 1700 $^{O}$C maximum and the cycle times should be programmable from 18 minutes and upwards. This furnace became a true success story and since 1997 we have continued to develop the concept and delivered numbers of them to three different continents. The following text is describing the main principles of why this special furnace has become so popular among its users.

The production of small ceramic components is in general still rather traditional. The pure powders are treated and shaped in green state. The green bodies are then pre-sintered and sintered. Although automation has been introduced into several steps of the production, the sintering is still very conventional. When production has increased the charges have increased in size and been loaded into larger kilns.

Our main point is to raise the question; is it reasonable to continue to sinter small components in periodic furnaces? We at Entech do not believe so. For the production of many of the smaller ceramic components it is time to change to leaner methods.

Time and energy could be saved by switching to a continuous process. Regarding the time factor the furnace does not have to wait for numerous components in order to be charged. The batch size can be very small, and as soon as the batch size is filled it is possible to conduct a charging cycle. Also the building of the giant stacks of the past will never be an issue.

The most important time saver is however the rapid cooling of the goods. The cooling is adjustable by the programming of the cycle times. In normal periodic sintering this is not possible when the goods are cooled together with the natural, or in best case enhanced, cooling of the furnace. In that case a cooling time of 3 hours is a good figure only achieved in small batch furnaces.
In our continuous furnace it is the thermal shock resistance of the component which sets the limit. Normal total cycle times for small components (up to 1700 $^{O}$C) can be as low as 60 minutes from cold to cold.

As mentioned earlier, not only time, but also energy is saved as the furnace is kept at steady state temperature all the time. The extra energy added is only corresponding to the heat transfer needed for the heating of the goods.

The lean production comes from the continuous flow. With continuous feeding you will also gain continuous access to finished products. Products can be inspected and shipped as soon as the order amount has been produced. With standard sintering methods your customers order will be finished together with all the other orders that are sharing the same charge. After waiting, all of the orders will suddenly be ready at the same time. If you as in most cases need to commit quality control, all of the orders will be queued for density check and microscopy at the same time.

When the benefits seem so obvious one might ask: Why now? Why not earlier? The main answer for this question is that the market has not been asking for this production equipment. The industrial production of small ceramic components is still relatively young.

The production of bioceramic components has often begun with small scale production in laboratories. As the business has grown the furnaces have grown. On short term it is more convenient to stick to a validated production process rather than turning the world upside down.

Another reason may be that some of the small component producers have sprung from traditional ceramic production by adding a “hi-tech” division to their companies. The traditions from sanitary ware or floor tiles have however not disappeared since the people, their location and values have been the same. What has been done for centuries can´t be totally wrong, can it?

The equipment has not been available either. When we started this project more than ten years ago there were no furnaces like this on the market. All the continuous furnaces were designed for lower temperatures and for heat treatment of heavy metallic or ceramic structures. The existing furnaces were belt driven, walking beam- or pusher type. The maximum temperatures were too low for high purity powders. Normal cycle times could vary from 8 hours up to 96 hours.

The ECRF (Entech Continuous Rotary Furnace) is a new way of having things done. The main advantages of this furnace are found within the production of thin walled oxide ceramic components. The products may be ceramic cog wheels, ceramic needles or any bio-ceramic component.

Let us then study the basic technology that has made this possible. The ECRF is based on a traditional carousel furnace design. The point for loading and unloading is the same, which only demands one opening to the furnace chamber. Compared to a feed through furnace there is much less air streaming through.

The hot zone is placed in the inner third (opposite of the opening) of the furnace cavity, and is equipped with $MoSi_2$ elements which are hanging through the furnace roof. Between the hot zone and on the both sides towards the furnace opening the roof is equipped with radiation shields made out of highest quality alumina fibre material. This design does not give a linear heating ramp. We have however found out that the increase and decrease in temperature is steady enough and very much repeatable.

The rotating hearth is corresponding to a rotating feeder disc which is placed outside of the furnace. Each tray position on the feeder disc corresponds to a certain location on the hearth. The goods are unloaded and loaded by means of a pneumatic pick and place unit in the following steps:

First one tray with sintered material is been picked out and placed onto the feeder disc, and then the feeder disc makes one rotation step. In the next step the robot picks up the new tray from the new position on the feeder disc and puts it into the furnace hearth, and finally the furnace hearth makes one rotation step.

If the furnace was empty to begin with there is no difference other than that the robot does not manage to bring anything out. The moves are conducted in any case and without any harm done.

After this unloading and loading cycle the robot will wait for the next start command from the PLC-system. The time in between is two start commands is called the cycle time. The cycle time is freely adjustable and the customers set this as low as the products safely can cope with. From our experience we are discussing a totally different scale. While many companies still are counting days and hours, our customers are setting the cycle time in minutes. ❑