Shinagawa Refractories Australasia Pty. Ltd. "Product Selection for Alumina Calciner Applications"

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Abstract

Calcination is the final step in the production of smelter grade alumina from bauxite and modern design alumina calciners use the fluid bed calcination process. While there are many different refractory materials used throughout a calciner, this paper will focus on the monolithic materials used in the main calciner, cyclones and ductwork of a fluid bed calciner.

1. Introduction

Alumina refining is the process of converting bauxite into alumina. The process is known as the Bayer process and involves four stages: digestion, clarification, precipitation and calcination. Material from the precipitation stage, known as hydrate is processed at high temperatures to remove the chemically combined moisture from the structure thus producing smelter grade alumina.

Traditionally the calcination process was conducted in rotary kilns however modern designs for the production of smelter grade alumina now use fluid bed calcination. These units are generally divided into three main stages-preheat, calcining and cooling with each zone containing a series of cyclones and ductwork that carries the alumina through the process. Throughout this process there are vessels and ductwork that operate at varying temperatures. In Fig. 1 the preheating stage cyclones and

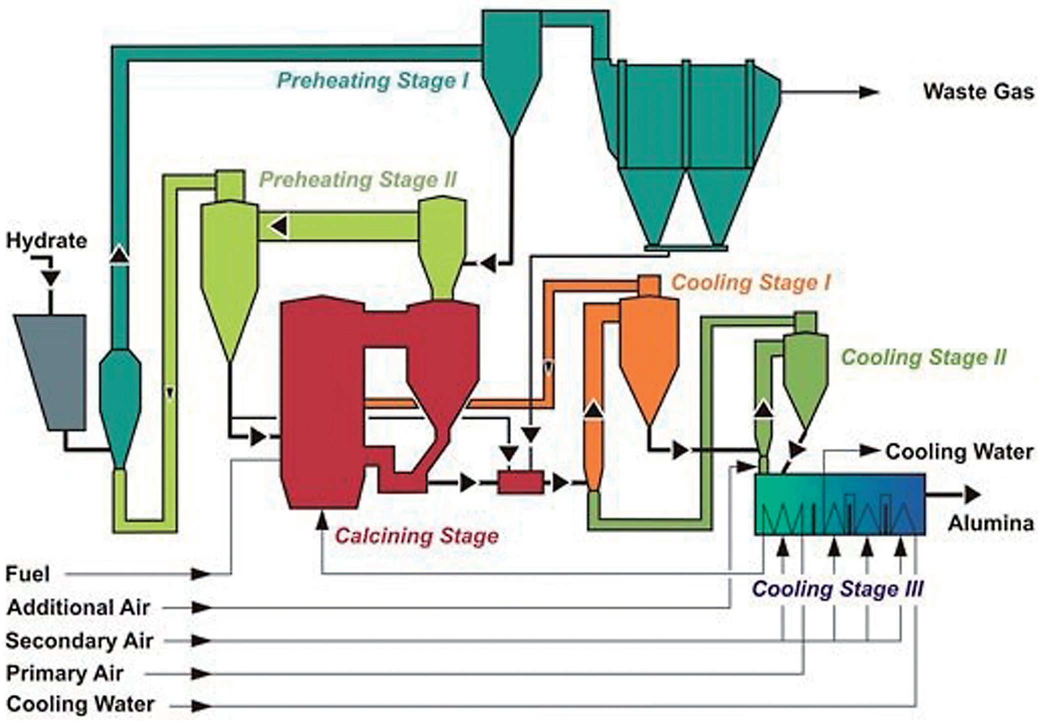

Fig. 1 Diagram of the alumina calcination process courtesy of Outotec.

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ductwork operate from 150 up to 350℃ and the cooling stage cyclones operate between 350 and 550℃. The main calcining stage consists of a fluid bed calciner and adjoining holding vessel and operates at approximately 970℃. The calciner unit experiences different mineral velocity depending on the vessel geometry and the material requirements are changed to suit the conditions present in particular areas of the equipment.

2. Vessel Design and Lining Configuration

The main design considerations for an alumina calciner are not significantly different to other mineral process applications. The aim of the refractory lining is to protect the steel shell from the heat and velocity of the feed mineral while maintaining the main design aspects of the calciner that are set by the equipment designer. The combination of an insulation layer and a dense working lining is used to provide a hard, abrasion resistant layer while maintaining heat within the vessel. The actual thickness of each of the components of the lining is determined as part of the design process and must be calculated by having a known overall lining thickness and a known final shell temperature. From this point the thermal conductivity of the candidate materials is used to calculate final shell temperatures at varying thicknesses of insulation and hot face materials with the configuration that meets the required shell temperatures used as the final lining design. Fig. 2 shows the calculated shell temperature of a proposed lining design for the recycle cyclone barrel, the internal operating temperature is 970℃ and the resulting shell temperature is 118℃ using a combination of 160mm of SHIRALITE 125XW and 120mm of SHIRACRETE 45.

3. Main Wear Mechanisms and Required Physical Properties

As a process that conveys fine particles at high velocities, the main wear mechanism in most areas of a calciner is erosion and the key material properties required is high density, high strength and high resistance to abrasion. In the past, conventional castables and gunning materials, along with clay and phosphate bonded plastics were widely used in alumina calciners however the use of low cement casting and gunning is now the industry standard in Australia and has contributed significantly to the overall life cycle improvement of a calciner. In more recent times, more understanding has been gained on the effect of thermal cycling on the requirements of a refractory used in calciners and more products with resistance to thermal cycling are being used. The main methods used to combat the effect of thermal cycling on refractory life is to use the addition of stainless steel needles to the installed lining or the selection of materials that are inherently better at withstanding the stresses induced by thermal cycling. These materials include products based on andalusite or fused silica grains however the use of fused silica is limited due to its lower service temperature and also its relatively low resistance to abrasion.

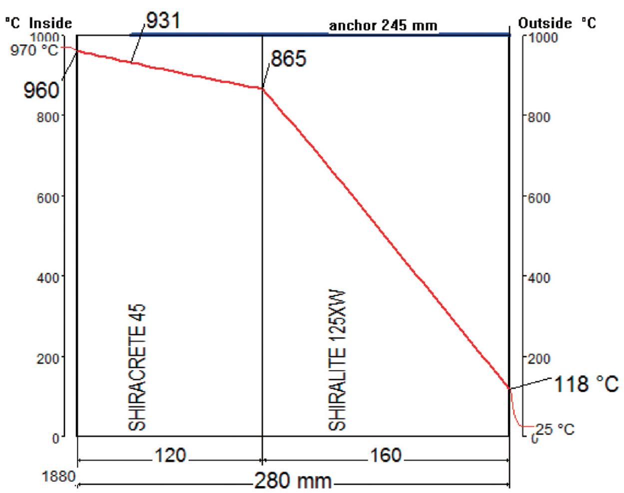

Fig. 2 Typical heat flow calculation diagram used in lining design.

The main role of the insulation layer is to maintaining heat within the vessel thus reducing the resulting kilns shell temperature. Insulation grades used will depend on the operating temperature of the vessel in which they are to be installed. Some areas will be operating at higher temperatures and thus need to be able to maintain performance at the interface temperature of that vessel. Other areas may operate a lower temperatures and require lower temperature rated products. Regardless of the products used, the insulation grade must be able to mechanically withstand the installation of the hot face material. Some lightweight materials have very low cured strength and hence are not suitable to have low cement gunning monolithic installed on top of them as the impact and velocity of the low cement gunning product may damage the insulation layer. Table 1 shows the typical properties of a selection of insulation products suitable for use in different areas of an alumina calciner. Each of these products are able to be installed by casting or gunning.

Hot face products typically used in calciners from the Shinagawa Refractories Australasia range are based on either calcined clays such as chamotte / synthetic mullite or andalusite. Bauxite based products can be used to target areas where high abrasion resistance is required and products that use a blend of aggregates are also used for specific physical property requirements. Typical physical properties of hot face materials used by SRA are shown in Table 2 for casting grades and Table 3 for gunning grades. For both the casting and gunning range it can be seen that the physical properties follow similar trends. Bulk density increases as alumina content increases due to the increase in density of the grain used in the product. Generally the strengths are similar across the range however there is a difference in both strength and abrasion resistance of the andalusite based materials compared to the chamotte and bauxite based products. The materials based on calcined clays such as SHIRCRETE 45 and SHIRAGUN 155 are used in the main areas of the calciners including cyclones, ductwork and also in the

Table 1 Typical property requirements for insulation grades after firing to 1000℃

Property	SHIRALITE 125MW	SHIRALITE 125XW	SHIRALITE 110XW
Location	Cyclones, Ducts	Fluid Bed Calciner, Cyclones, Ducts	Fluid Bed Calciner
BD(kg/m^3)	1400—1600	800 - 900	350 - 600
CCS (MPa)	> 10.0	0.7 - 3.0	0.2 - 0.8
PLC (%)	-0.6 to 0.1	-0.9 to -0.3	-1.5 to -0.3

Table 2 Typical properties of hot face casting grades after firing to 1000℃

Property	Casting Grades		
	SHIRACRETE 45	SHIRACRETE 60AD	SHIRACRETE FS75
Base Aggregate	Calcined Clays	Andalusite	Fused Silica
Location	Fluid Bed Calciner, Cyclones, Ducts	Ducts, Mixing Pot	Seal Pot
BD (kg/m^3)	2250 - 2500	2500 - 2650	2020 - 2120
CCS (MPa)	> 70	> 60	> 80
MOR (MPa)	> 8	> 6	> 8
Abrasion Index* (cm^3)	< 7	< 9	< 18
PLC (%)	-0.5 to 0.0	-0.5 to 0.0	-0.3 to 0.0
Al_2O_3	48	60	21
SiO_2	47	37	76
CaO	2.1	2.0	2.1
Fe_2O_3	0.6	0.6	0.2

*Abrasion Index is a measure of erodability of the refractory material when blasted with SiC for 7 minutes at controlled pressures. The result is expressed as a volume loss in cubic centimeters

Table 3 Typical properties of hot face gunning grades after firing to 1000℃

Property	Gunning Grades			
	SHIRAGUN 155	SHIRAGUN 165AD	SHIRAGUN 170AD	SHIRAGUN 175
Base Aggregate	Calcined Clays	Andalusite	Bauxite / Andalusite	Bauxite
Location	Cooling Cyclones, Ducts	Fluid Bed Calciner, Holding Vessel	Fluid Bed Calciner, Holding Vessel	Cyclone inlets, High velocity ducts
BD (kg/m^3)	2000 - 2550	2300 - 2500	2420 - 2520	2470 - 2530
CCS (MPa)	> 60	> 50	> 60	> 80
MOR (MPa)	> 6	> 6	> 7	> 10
PLC (%)	-0.6 to 0.0	-0.6 to 0.0	-0.4 to 0.0	-0.4 to 0.0
Abrasion Index(cm^3)	< 11	< 12	< 9	< 6
Retained Strength (%)	50%	80%	80%	60%
Al_2O_3	50	60	74	80
SiO_2	45	35	21	11
CaO	2.3	2.5	2.5	2.4
Fe_2O_3	0.7	0.6	0.8	1.1

Abrasion Index is a measure of erodability of the refractory material when blasted with SiC under controlled conditions. The result is expressed as a volume loss in cubic centimeters.

Retained strength is the measure of thermal shock resistance where a sample is cycled to 1000℃ 5 times and then tested for MOR. The result percent retained strength is shown as a percentage of a standard (non cycled) sample

calcining vessel itself. Andalusite based products such as SHIRACRETE 60AD and SHIRAGUN 165AD have increased thermal shock resistance compared to bauxite and chamotte based products and are used in specific areas of a calciner where particle velocity is lower and the impact of thermal cycling is more prevalent such as the main calcining vessel in place of chamotte based products. Specialty products such as SHIRAGUN 175 and SHIRACRETE FS75 are used in specific areas to target the main wear mechanisms. SHIRAGUN 175 is very abrasion resistant and is used in high velocity areas such as cyclone inlets and narrow ductwork that suffer from abrasion. SHIRAGUN 170AD is a product that was specifically developed by SRA to have a combination of abrasion resistance and thermal shock resistance. It was designed to fit into areas that have a combination of thermal cycling but are still subject to abrasion such as the fluid bed calciner and the holding vessel.

4. Installation Method

The product type and hence installation method selected are largely dependent on the type of project being undertaken. Generally new construction projects, known as Greenfield projects involve a large construction process of which the refractory installation work is a small part. In these projects the allowable refractory installation timeframe is longer and thus allows more time to be taken for the installation. These types of works allow for the installation of low cement castables by vibration casting which generally take longer to install than gunned linings. Gunned linings are still used in certain parts of a new construction process however the majority of installation will be conducted by casting. The main advantage of a cast repair is that generally the physical properties of the vibration cast low cement castable will be higher than that of a comparable low cement gunning material. The increased bulk density and lower porosity give a better resistance to the abrasive nature of the process. In addition to this, when a cast lining is installed the addition of stainless steel needles is simplified. The addition of the steel needles at the mixer is more easily achieved than the addition in the gunned repair and is safer for workers as there is no high velocity steel in the environment during installation.

Gunned installations are more suited to in situ repairs of calciner units. Fig. 3 shows the gunning installation of SHIRAGUN into the roof of a cyclone-gunning of the roof areas in cyclones is simpler than casting. During the life of a calciner the time allowed for repairs is much shorter so the installation methods is required to be as fast as possible to allow the units to be brought back on line and producing alumina as quickly as possible.

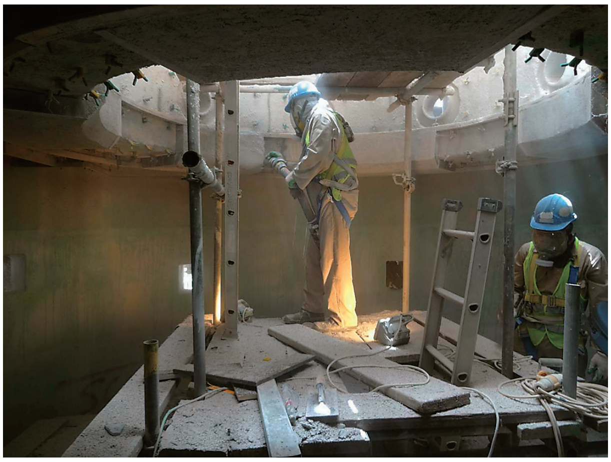

Fig. 3 Gunned installation of SHIRAGUN.

While the physical properties such as abrasion index are slightly lower on gunned versions of the products, there is much more benefit seen in the speed and ease of installation of a gunned product. As downtime for a calciner becomes more and more important, there is more and more pressure placed on reducing the length of maintenance outages. Areas for future improvement are being investigated and these include the use of wet gunning (shotcrete) products for even faster installation rates and also the use of shorter curing times and faster heatup rates when the lining is being dried out. These aspects of an installation are critical to the overall performance of the refractory lining in the calciner and must be carefully considered before implementation.

5. Summary

Shinagawa Refractories Australasia has supplied a large amount of low cement casting and gunning materials into alumina calcination units in Australia and around the world in the form of SHIRALITE, SHIRACRETE and SHIRAGUN ranges of products. The process involves careful design work to ensure that the key parameters of the design are met and then selecting the products that will ensure that the best performance is achieved by the lining.