ALMATIS GLOBAL PRODUCT CONCEPT FOR THE REFRACTORY INDUSTRY

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ABSTRACT

This paper describes how Almatis as a global supplier of premium alumina raw materials supports customers in the refractory industry to enhance their business in a more and more globalised business environment. In addition, key trends in the steel and the refractory industry are discussed. Finally, the Almatis global product concept is introduced.

ALMATIS GLOBAL PREMIUM ALUMINA SUPPLIER

In March 2004 the specialty chemicals business was sold by Alcoa to private equity firms and became Almatis. Almatis is a stand alone company and has a clear focus on the global and secure supply of premium aluminas. Almatis recently has made considerable investment in premium alumina manufacturing facilities:

- Multi million dollar investment in large batch mill capacity in Ludwigshafen, Germany (March 2004), and re-started ground reactive aluminas batch mill in Bauxite, Arkansas, U.S. (June 2004),
- Major investment ($18 million) in a fully integrated tabular alumina facility with approximately 85-90,000 mt sized tabular capacity in Qingdao, China, to expand existing tabular capacities (July 2004, to be operational in March 2006).

A further important investment in 2005 is the introduction of the new global integrated software system SAP R3 within Almatis. It will further contribute to a harmonisation of processes such as customer order handling and global demand management.

In the late 1990s the ABS (Almatis Business System) was initiated in the Rotterdam cement plant and subsequently implemented in all Almatis plants worldwide. The system was developed from the Toyota Production System and means a change from a classical push to an advanced pull system. The ABS is described in detail by Post et al. [1].

Almatis ensures consistency of supply by multiple manufacturing locations worldwide, as shown in **Figure 1**. New sales offices in China have been opened in Shanghai in November 2004, and Kaifeng in January 2005. In addition, a global network of agents and distributors with local warehousing ensures the desired proximity to customers.

Product development and technical customer support are a fundamental part of Almatis´ market strategy, which is supported by applications laboratories in all regions.

Having started already in the year 2000, several task teams within Almatis, each responsible for a certain product line, investigated how to support the key changes in our refractory customers´ industry, and how to position Almatis products for the future. As a result, Almatis decided to undertake a major change in its product offering and offers certain key products from within its refractory portfolio as “Global Products”.

These selected products are produced around the world in all Almatis plants to the same specifications. In cases where this has proved not to be the best option, it has been decided to identify the “Center of Excellence” for a certain product line and to concentrate all production for these products in this selected superior plant.

The Global Product concept will help Almatis´ customers to further reduce their costs. It will enable research and development departments to access similar raw materials worldwide. Reformulation and regional adjustment of products due to variations in raw materials will become the rare exception rather than the rule. Production facilities around the world have access to similar raw materials. When new refractory products are being developed for a global market in the future, this can be done more efficiently during the development phase when all formulations can be based as near as possible on these Global Products.

Before the Global Product concept for Tabular Alumina and the other product lines of the Almatis raw material portfolio are presented in more detail, the key trends in the global steel and refractory industries will be discussed to give a better understanding of the business environment.

Fig. 1: Almatis locations worldwide (RCP products)

TRENDS IN THE STEEL INDUSTRY

The steel industry is the main consumer of refractories, accounting for 60-70 % of the consumption. Therefore, the first focus of the discussion will be on the global trends in the steel industry. Since 2000, the steel market has shown an unpredicted boom due to the growth in China (**Fig. 2**).

Also in South America and other parts of Asia, the steel market is steadily growing. However, the growth in the mature markets - Europe, North America, and Japan is limited. The growing steel markets are summarised as "BRIC", which stands for Brazil, Russia, India, and China. The BRIC´s share in world steel production is shown in **Figure 3**, and predicted by Olsher [3] to account for 50 % of the world steel production in 2010. Dollé [4] forecasts an increase of steel volumes by 2015 of about 425 million tonnes worldwide, of which BRIC accounts for about 273 million tonnes. This would result in about 50 % share of BRIC in the world steel market.

A key driver for this development is, of course, the growth of demand in the developing economies. The steel consumption per capita is much lower in BRIC compared to the mature markets (**Fig. 4**). In addition other advantages of BRIC play an important role, like close proximity to raw material resources, lower labor costs, and energy. The cost leadership of the BRIC´s can be ranked by full costs of steel slabs (2003) in Euro per tonne [3]: Russia < Brazil < ... < China < India < Japan < ... < EU 15 < NAFTA. And the steel industry profitability (margins) is clearly higher in BRIC [7].

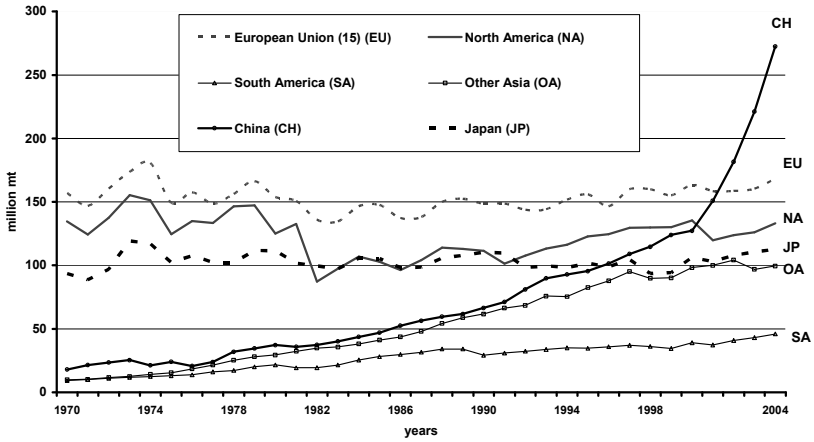

Fig. 2: Crude steel production per region 1970-2004 [2]

The steel industry has shown major progress in consolidation during the last few years, although the degree of concentration is still much lower compared to other industries like the automotive industry, or other base industries like cement and aluminium [4]. Examples of consolidation at an international level are Mittal Steel (largest steel company after the recent take over of ISG in North America); Arcelor (strong European base, but also presence in all BRIC regions); JFE, and Nippon Steel, Kobe, Sumitomo (all Japan); US Steel and National Steel (North America) and others. Dollé [4] described in the long term a world steel consumption of around 1.5 billion tonnes in 2015 with major players in the range of 70 to 140 million tonnes per year. Consolidation will continue until the top 5 to 10 steel producers represent 50 % of world production.

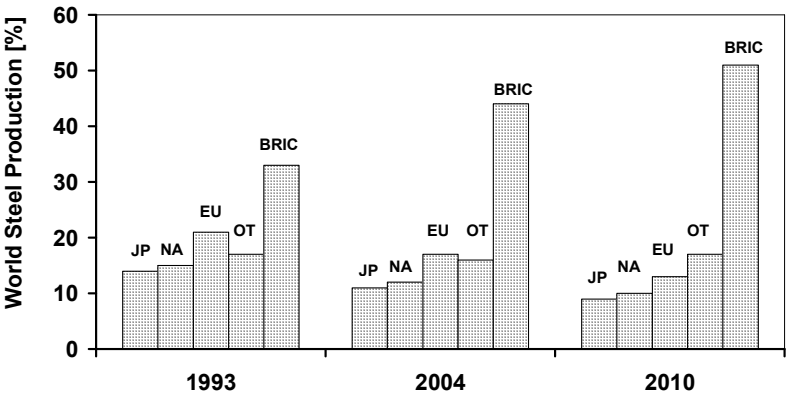

Fig 3: BRIC's (Brazil, Russia, China, India) impact on worldwide steel production, OT=other [3]

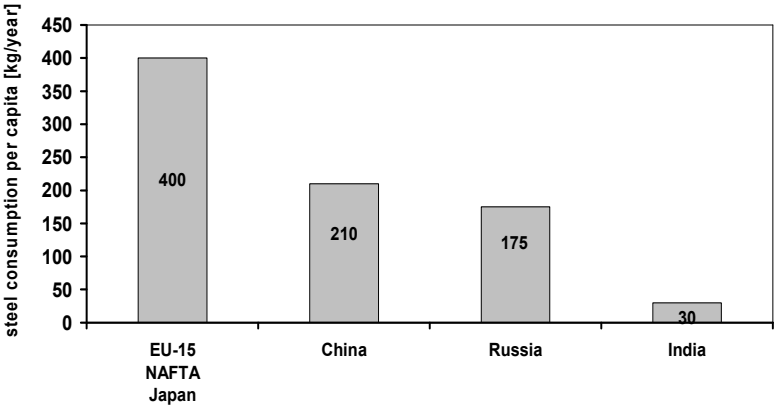

Fig 4: Steel consumption per capita [5,6]

REFRACTORY UNIT CONSUMPTION FOR STEEL MAKING

Another important trend for the refractory industry worldwide is the decreasing specific refractory consumption in the production of steel (**Fig. 5**). The development and improvement of the steel producing technology in combination with much higher process demands on the refractory linings have resulted in a constant decrease of specific refractory consumption from about 50 kg/t in the 1960´s to a level of 8-10 kg/t today for modern steel manufacturing.

On the other hand, this decrease in specific consumption has been accompanied by an increasing use of higher quality refractories, e.g. based on synthetical raw materials, which are technically required by the much more severe service conditions of the new steel making technologies.

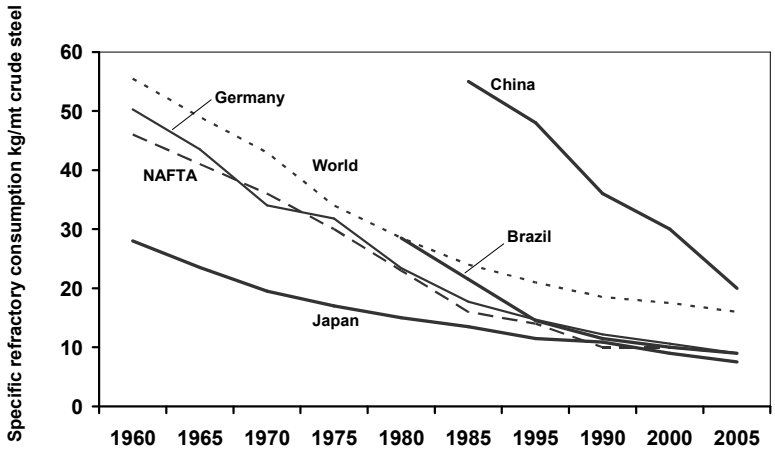

Fig. 5: Steel industry specific refractory consumption trend [8-12]

Examples of these steel technology changes are Basic Oxygen Furnace (BOF) replacing Open Hearth Furnace, the introduction of Continuous Casting, and the important growth of Secondary Metallurgy performed in steel ladles. These changes have been discussed in more detail with regard to alumina refractories in previous papers [13,14].

Meier and Pirker [15] assume a reduction in the specific refractory consumption of between 1.2 to 1.7 % per year, naturally considering that there will be regional differences according to the processes and materials involved. Minoru [16] reports a decrease of unit consumption of refractories for steel making in Japan from 15.3 kg/t in 1980 to 8.0 kg/t in 2002, a drop of approximately 50 %.

The remarkable decrease in unit consumption of refractories has lead to significant overcapacities in the refractory market. According to Meier and Pirker [15], only 60-65 % of the capacity is in use and therefore the competitive pressure increases continuously.

The number of refractory companies in China is estimated to be about 2000, but no clear figure is available. The Chinese figure of 20 kg/t for unit consumption in 2005 is a best estimate of the China Refractory Industry Association. The unit refractory consumption in China is currently about twice that of other regions (**Fig. 5**). Assuming, that it will decrease to a comparable level of about 10 kg/t in future, one must also expect substantial overcapacity within the Chinese refractory market in future. Part of the problem may be overcome by the absolute growth of steel production in China. It is not easy to determine the final impact on the global refractory market.

REGIONAL DEMAND FOR HIGH QUALITY MATERIALS

In the emerging markets the local end user industries such as the automotive industry have an increasing demand for locally produced high quality steels [17]. They require from the local steel producers advanced steel making technology including high quality refractory materials for the linings of the metallurgical vessels. Li [18] from Bao Steel in China phrased it: “high class refractories make high class steels.” And high quality refractories require high quality raw materials. In Japan, the consumption ratio of natural raw materials for refractories decreased from 1980 to 2002 by about 20 %, whereas the consumption of synthetical raw materials increased by 20 % [16]. The total consumption ratio in 2002 is 52 % for natural and 41 % for synthetical raw materials, the remaining 7 % is reclaimed bricks.

The increasing demand for high quality refractories in the developing regions is leading to construction of new plants by the global suppliers, joint ventures with established local manufacturers, and an increased technology transfer by licensing.

GLOBALISATION AND CONSOLIDATION IN THE REFRACTORY INDUSTRY

The steel industry has been a strong buyer for many years due to its high consumption of refractories and the overcapacity in the refractory industry. With the ongoing consolidation, steel will become an even stronger buyer and consequently, the refractory industry also will need to consolidate to keep and improve its position in the business. Examples of the substantial consolidation and re-structuring within the refractory industry during the past few years are RHI and Vesuvius, both of which have formed global companies by merger and acquisitions, Krosaki Harima in Japan, and most recently, Plibrico International and Lafarge Refractories as part of the Imerys organisation.

The sales turnover (2003) of global refractory companies is shown in **Figure 6**. These five companies account for about 25 % of the estimated global refractory sales turnover. Brown [20] reports, that “in the U.S. and Canada during the period from 1999 to 2004 over 750,000 tons of refractory production capacity has been eliminated due to industry consolidation and rationalisation. A total of 42 refractory plants have closed.”

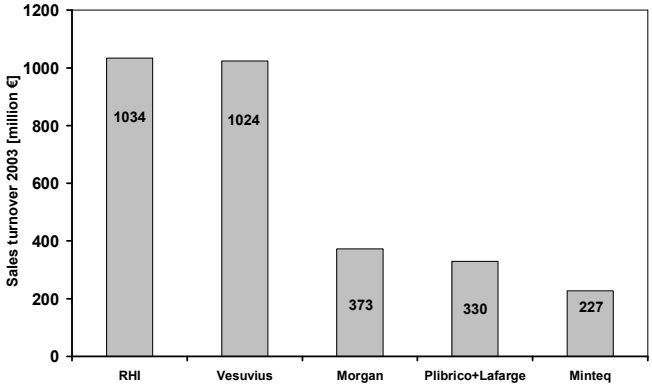

Fig. 6: Sales turnover of global refractory companies 2003 [19]. These companies account for about 25% of the estimated global refractory sales turnover.

Figure 7 shows a world map with manufacturing locations of global refractory companies. For clarity, the manufacturing locations have been consolidated per manufacturer and country. This has been necessary especially for Europe due to the high number of locations within the same country.

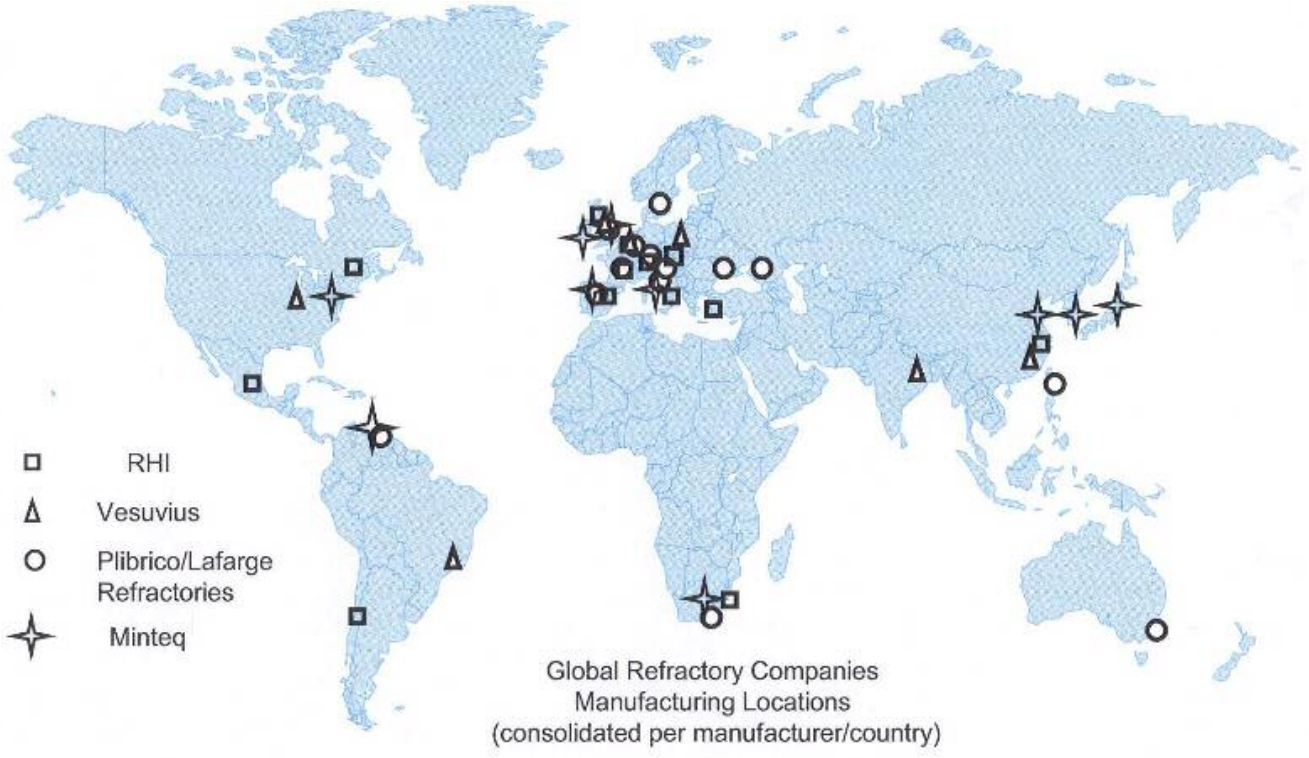

Fig. 7: Manufacturing countries of global refractory companies. Consolidated per manufacturer and country for clarity

The never ending need for reduced costs to gain competitiveness in global markets has generated substantial changes in the way refractory companies deal with their producing locations and their product portfolio. Products that were previously produced in several plants are now produced in fewer but more specialised plants, in some cases in only one plant. Other locations have been closed and production moved to other regions of the world. Products that cannot be produced competitively are now toll manufactured by partner companies.

Consequences of these developments can be summarised as:

- Increasing technology transfer
- Re-formulation of recipes to adjust to locally available raw materials,
- Cross qualification of new raw materials, e.g. in case of licensing,
- Qualification trials not only on a lab scale, but often including plant trials and, even more time and resource consuming end customer qualification trials,
- Last but not least, also a constant requirement for technical innovations including services to sustain and develop the position in an increasingly competitive environment, where changes happen much faster and quick decisions and actions are important [10].

CHINESE REFRACTORY RAW MATERIALS

An important change during the past three years is the growing problem of availability, quality, and price increases of Chinese raw materials for example Bauxite, Brown Fused Alumina, and Magnesia, where China is the main supplier worldwide. The reason for this is the unpredicted steel production growth in China, which has significantly increased the refractory consumption in China. This growth has also consumed refractory raw material capacity which had previously generated products for export. Chinese raw material problems are mentioned and discussed by several authors [10,21,22]. The price increases of raw materials are discussed e.g. by Meier and Pirker [23] and Semler [10].

Many refractory companies, and not only the global players, had to spend a remarkable share of their research and development resources for re-qualification purposes due to the Chinese raw material issues stated above. These resources have not been available for value-creating new developments and innovations.

REQUIREMENTS FOR REFRACTORY RAW MATERIALS AND SUPPLIERS

The key changes in the refractory industry described above have an impact on the requirements for refractory raw materials and the suppliers of those materials. They can be summarised as follows:

- Global and secure availability of high quality materials, especially synthetic raw materials taking into consideration the trends in the steel making technology,
- Consistent and reliable quality level, also taking into consideration ISO 9001 and ISO 14001 certification [23],
- Standardisation of raw materials and their specifications to reduce and accelerate re-formulation and cross qualification work of R&D departments and end customers,
- Ongoing development of new, innovative material solutions, with regard to automated, cost effective monolithic lining technologies,
- Economy of scale and competitive cost structures.

Meier [24] describes further necessary characteristics of leading mineral suppliers as: a clear strategic focus, because the markets are becoming increasingly more transparent; specialisation; and long term cooperative agreements and economical alternatives for the refractory customers.

Standardisation of raw materials and their specifications is reasonable and sounds pretty simple, but unfortunately it is not. The difficulty is in the detail, and so a real standardisation covers not only chemical or physical properties like bulk density or apparent porosity, but also e.g. specifications for the particle size distribution. Here, different screen systems (mm vs. mesh) can be used, or various equipment is used for the measurement of fine and super ground products. If high volume raw materials are to be produced and supplied locally, production equipment and processes need to be adequate to achieve the same product properties as in other producing locations.

Almatis as a global player in the field of synthetic alumina based raw materials has spent considerable effort to support the key changes in its customers´ industry. In addition to its global presence by multiple manufacturing locations, sales offices, and application laboratories worldwide, a Global Product concept has been developed. It will be discussed for the major product lines of the Almatis raw material portfolio in the following chapters.

ALMATIS GLOBAL TABULAR PRODUCT CONCEPT

T60/T64 is one product. Historically, the name T60 was used in all countries except North America, and T64 was used for the North American market. Therefore, for the global tabular products the name T60/T64 is used.

Since 2001, 14 standard grades have been offered as Global Products. Additional special regional grades are available on request. The chemical specification was harmonised in 2001.

Table I: Global T60/T64 tabular alumina products, number in parenthesis is Tyler mesh

Open Sizes	T60/T64 0-3MM(-6)
	T60/T64 0-1MM(-14)
	T60/T64 0-0.5MM(-28)
	T60/T64 0-0.3MM(-48)
	T60/T64 0-0.2MM(-65)
	T60/T64 -45MY(-325) LI
	T60/T64 -45MY(-325) STD
	T60/T64 -20MY
Closed Sizes	T60/T64 3-6MM(3-6)
	T60/T64 2-5MM(1/4”-8)
	T60/T64 1-3MM(6-14)
	T60/T64 1-2MM(8-14)
	T60/T64 0.5-1MM(14-28)
	T60/T64 0.2-0.6MM(28-48)

The particle size distribution is specified in mm and Tyler mesh, with equivalent sieves across the whole particle size distribution. Also, the test methods and the information provided on the Certificate of Analysis (CoA) have been harmonised for the tabular products.

Tabular Alumina T60/T64 is globally available from 5 plants (Rotterdam, The Netherlands; Ludwigshafen, Germany; Leetsdale, North America; Falta, India; Qingdao, China) to the same specifications.

In the meantime, the global tabular product concept has proved its value on the global market place. The technology transfer processes of our customers have become much easier, because formulations do not need to be adjusted with regard to particle size distribution, if global tabular sizes are used. Also resources and time consuming additional testing and qualification of finished products by the end-user can be reduced or even avoided.

T60 is a regional Tabular Alumina produced at Iwakuni, Japan. It has a lower Na_2O content compared

to standard T60/T64 (max. 0.2% vs. 0.4%) and a higher bulk specific gravity compared to standard T60/T64 (typically 3.7 vs. 3.55 g/cm³). The sizes are not yet harmonised with the global tabular products, although the particle size distribution for most of the sizes is similar to T60/T64 global products.

CALCIUM ALUMINATE CEMENTS

In 2001, an optimization study was undertaken to improve the competitiveness on quality, product offering and cost position for Almatis cement supply worldwide. Rotterdam was identified as the Center of Excellence for cement manufacturing. In order to offer the market the best possible cement products, the manufacturing of calcium aluminate cement has been focussed in Rotterdam. All Almatis cement grades are supplied as Global Products from Rotterdam to all customers worldwide.

Almatis produces high purity calcium aluminate cements with 70 and 80 % Al_2O_3 content. The products are widely used throughout the refractory industry, and also in other areas such as the construction industry. The Almatis cement production process is designed to achieve maximum consistency. The cement setting times are precisely controlled by tight control of the cement phases.

Two product types, CA-14 and CA-270, represent the 70 % alumina cements. In the refractory industry they are used particularly in low and ultra-low cement, low moisture castables for gunning, vibration or self-flowing placement. Almatis´ 70 % alumina cements do not contain any organic additives so that they give full flexibility in product design without any potential chemical mismatches. The CA-14 cement is produced with three distinct setting time ranges with short (CA-14 W ´winter´), medium (CA-14 M), and long setting times (CA-14 S ´summer´). CA-270 is a product characterized by very low water demand, excellent flowability, and high strength development.

CA-25 R (Regular Grade), CA-25 M (medium), and CA-25 C (Casting Grade) represent Almatis 80 % alumina cements. CA-25 C has a longer working time than CA-25 R and a lower water demand. CA-25 M was introduced in 2003 as a cement with a medium setting time range.

CALCINED AND REACTIVE ALUMINAS

Calcined and reactive aluminas are required for various refractory applications like refractory bricks, sliding gates, vibration and self-flowing castables, gunning and ramming mixes, and shotcreting. Almatis supplies a full range of calcined and reactive alumina products from Ludwigshafen, Germany, and the two US manufacturing locations Leetsdale, Pennsylvania and Bauxite, Arkansas. A global product data sheet was established 2001. It provides data for similar products as a comparison for global refractory customers.

Examples of comparable products:

CT9FG and A2-325 are calcined ground aluminas with a fineness of 45 µm (325 mesh), a d50 of about 5 µm, and a specific surface area (BET) of typically 0.6-0.8 m²/g.

CTC20 and A20SG are superground (< 20 µm) monomodal reactive aluminas with a d50 around 2 - 3 µm and a BET of typically 1.3 - 2 m²/g.

CL370C, A17NE, and A3000FL are superground bimodal reactive aluminas with a d50 around 2.5 - 3 µm and a BET of typically 2.6 - 3.0 m²/g.

CT3000SG and A1000SG, and CT4000SGR and RG100 are superground monomodal reactive aluminas with a d50 < 1µm and a BET of typically 7.5 - 8.4 m²/g.

CT10SG and A13-325 are high surface area aluminas with a d50 around 3 µm and a BET of about 12 m²/g.

Besides these aluminas, other specialities like the multimodal reactive aluminas CTC30, CTC40, CTC50, and CTC55 (contains Spinel) are produced only at Ludwigshafen but are offered worldwide. Recently, E-SY 1000 and 2000 (with Spinel) have been introduced as reactive aluminas for low dilatancy high performance castables, e.g. to achieve pumpability for shotcreting [25].

However, just providing a comparative data sheet for aluminas from different manufacturing regions is not considered to be sufficient for an Almatis global product concept. Reactive aluminas in particular are key tools for modern refractory formulations, both castables and bricks. They have a major impact on the water demand and rheological behaviour of castables and on the strength, porosity, slag-and wear resistance of the refractories [13,26]. A change of these components in a refractory mix often requires an undesired, intensive re-qualification effort. Therefore, recently a project has been started to further harmonise the key calcined and reactive alumina products by establishing global product names and specifications applicable for all regions.

OTHER SPECIALITY PRODUCTS

The following innovative Almatis products, which have been described in detail in various publications [13,27-29], are supplied from Ludwigshafen, Germany: Spinels (MR 66, AR 78, and AR 90), Dispersing Aluminas (ADS 1, ADS 3, ADW 1, and M-ADS 1, M-ADW 1), Super Lightweight Aggregate SLA-92, Almatis Integrated Matrix products (AIM), and Bonite, the recently introduced new dense calcium hexaluminate aggregate [30]. The Calcia free hydraulic binders Alphabond 300 and 500 [31] are supplied from Vidalia, Louisiana.

As appropriate, these products are warehoused in all regions to provide the desired one stop shopping for the refractory customers.

CONCLUSION

The key trends in the steel industry are the vast growth of steel production in the emerging regions BRIC, the ongoing consolidation on a global scale, the continuing development of steel producing technology and the decreasing unit refractory consumption for steel making. These trends call for 1) substantial re-structuring and consolidation in the refractory industry also on a global scale; 2) increasing technology transfer; 3) increasing supply of high quality refractory materials.

Based on the idea to offer the same high quality products in all regions worldwide, the Almatis Global Product concept accelerates the transfer of refractory formulations and reduces the cost for re-formulation and qualification trials. Standardisation is and will become an important tool adapting to the changing market.

Along with the global product concept Almatis supports its customers by offering the essential service and application knowledge. 20 locations worldwide ensure the close proximity to the customers in the main regions.

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