China Continues to Dominate Refractories Despite a Slowing Steel Industry

S. Shaw

China remains the largest producer of refractories, and is expected to account for more than two thirds of a global output of 37,3 Mt in 2019. It is also the largest supplier of refractory raw materials for its own consumption as well as for export. Strengthening Chinese environmental regulations, rising Chinese production costs, and high raw material prices continue to have an impact on refractories in the wider global market. Some of the most important industrial minerals for use in refractories are graphite, alumina and magnesia – which have also been some of materials the most widely affected by price rises in recent years.

Prevailing refractory raw material prices

China's importance throughout the refractory supply chain allows it to dictate pricing but rising production costs in the country are having a large impact on prices across the industry. China's energy and labour costs continue to rise while, on the raw material side, many of its resources are becoming harder and more expensive to mine.

Strengthening Chinese environmental regulations, however, have had the largest impact on production costs across most mineral supply chains. In the first half of the 2010s, environmental inspections in China were carried out by local government officials who were reluctant to enforce closures because it would result in a loss in revenue. Industrial mineral producers upgraded plant equipment but failed to change processing techniques and most were relatively quick to re-open (although some capacity has been lost permanently).

From 2015, the national government took more direct control to improve environment problems. A total of 134 environmental protection courts were established across China to oversee stricter implementation of environmental laws across a range of industries. With enforcement now under national control, closures were widespread and stricter penalties enforced. While most closures were still temporary, there were much longer delays in reopening with processors required to overhaul their technologies to meet higher wastewater, air quality, and other environmental standards.

Some capacity was closed permanently, mainly among smaller processors who were unable to afford such upgrades. China's new Environmental Protection Tax Law came into effect on 1 January 2018, and taxes began to be charged on all industries that discharged pollutants from April that year.

Prices for refractory minerals, including graphite, alumina and magnesia, increased from mid-2017 through 2018 as a result of Chinese production plant closures (as well as rising demand from non-refractory applications – in particular, there was strong growth for graphite in the lithium-ion battery industry). Refractory producers began to increase purchases and build stockpiles to guard against further price rises and the possibility of supply shortages.

Graphite

Graphite is used in shaped refractories such as magnesia-carbon and alumina-carbon bricks. All types of graphite can be used in refractories, but larger size natural flake graphite is typically preferred since it tends to have higher carbon grade and the shape lends itself to the final structure of the refractory. Despite lithium-ion batteries taking a rapidly increasing market share, refractories are still forecast to account for around half of global flake graphite consumption in 2019, an estimated 351 kt; an additional 130 kt of synthetic and natural amorphous graphite could also be used.

These figures are Roskill estimates as published in its new report Natural & Synthetic Graphite: Outlook to 2028, 12th Edition, released in June 2019.

China accounts for almost half of all flake graphite production worldwide. Chinese flake graphite processing plants have been targeted by Chinese environmental inspections because of their use of strong acids and other reagents as part of the method of purification to obtain the highest carbon grades. Although purification is usually associated which ultrahigh-grade battery material, the production of standard flake graphite for refractories was also affected.

Total Chinese flake production declined by around 30 % in 2016 before recovering in 2017 and then falling again by less than 10 % in 2018 as a result of two rounds of "look back" plant inspections in June (focussed on Heilongjiang) and October (focussed on Shandong) to check the progress of flake graphite processors meeting envi-

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*Roskill is speaking at UNITECR in Yokoham/JP, 13.–16.10.2019. Kerry Satterthwaite, Manager of the London Consultancy's Industrial Minerals & Chemicals Division, will speak further on China's continuing control of the refractories industry and what changes we can expect to see over the following decade.

ronmental targets. Further rounds of closures are expected to concentrate more closely on plants outside of the main manufacturing hubs and on alternative forms of pollution.
Although, the 2016 fall in production was relatively extreme, flake graphite prices were little influenced by these changes thanks to significant overcapacity in the Chinese flake industry and producers were able to draw down stocks to fill the supply gap. As closures continued into later years, however, flake prices began to rise. Prices for high carbon (94–97 % C) medium- and large-size flake graphite increased by 31 % and 25 % in September 2017 and again by 8 % and 15 % in the first quarter of 2018 (based on FastMarkets prices for CIF European port).
Flake graphite prices saw some downward readjustment in the period to mid-2019 as capacity re-opened, but prices remain high compared to mid-2017 (16 % higher for medium size flake and 26 % higher for large size flake at USD 843/t and USD 1010/t respectively in May – after which, these price series were discontinued). Large-size flake graphite is increasingly used in the emerging market of expandable/expanded graphite in China, which is to some extent in competition with refractory grades.
Although China is reported to have large resources of flake graphite (official Chinese estimates are in excess of 250 Mt), many deposits currently exploited are becoming more expensive to mine. When combined with rising labour, energy and environmental costs, China is now looking to foreign sources to sustain its increasing demand. Chinese imports of all natural graphite averaged yearly just 2–3 kt between 2010 and 2016, but increased to 6 kt in 2017 and 63 kt in 2018, with new supply coming mainly from Mozambique (mostly smaller size flake for use in the lithium-ion battery sector) and Madagascar (larger size flake for use in expandable/expanded graphite); all of these grades are suitable for use in refractories. China is expected to continue increasing its foreign imports over the coming years.

Bauxite and alumina

Refractories are an important market for the bauxite and alumina sector, forecast to account for 38 % of global Non-Metallurgical (NM) bauxite (on a raw bauxite basis) and 67 % of global calcined alumina consumption in 2019. This accounts for an estimated 4 Mt raw bauxite (equivalent to 3 Mt calcined bauxite once calcining losses are accounted for) and 2,9 Mt calcined alumina.
As described in Roskill's new report Non-metallurgical Bauxite & Alumina: Outlook to 2029, 10th edition, due for publication this August, refractories are by far the largest application for calcined alumina and an important application for NM bauxite. These materials are used in a variety of bricks (including alumina, alumina-carbon, alumina-spinel, alumina-magnesia-carbon, synthetic mullite) and monolithics.
Almost 2 Mt calcined bauxite is consumed directly in the form of refractory-grade calcined bauxite. Smaller amounts of abrasive-grade bauxite are also used indirectly as a feed for Brown Fused Alumina (BFA). The total amount of BFA used in refractories is estimated to be 0,8 Mt, with a further 0,2 Mt used in the production of Calcium Aluminate Cement (CAC) for refractories. China is the largest producer, consumer and exporter of refractory-grade calcined bauxite.
Guyana is the only other significant supplier to international markets, although some grades are produced in India and Russia for local markets. Primary markets for exports from China and Guyana are Europe, North America and Japan. The majority of NM alumina is also consumed directly, in the form of speciality calcined grades (calcined, tabular, and white fused); smaller amounts are also used in other ways. Calcined grades are used to produce very high alumina bricks and monolithics grading >90 % Al_2O_3.
Production of alumina refractories are principally concentrated in China, Europe, Japan and North America. There has been a general move towards the use of higher alumina refractories with the desire to prolong working lives for steel and other vessels as well as to help produce cleaner steels. The use of alumina refractories in China has lagged behind that in the rest of the world but is increasing. Specific consumption in China was around 0,4 kg per tonne of steel only six years ago compared to 1,2–1,4 per tonne in Europe, North America and Japan but, while specific consumption in other regions has seen little change, usage in China has continued to rise.
Problems with both raw and calcined bauxite supply have possibly accelerated the trend towards international best practice. Supply of Chinese bauxite and alumina has suffered from environmental shutdowns for a number of years now. Refractory-grade bauxite prices peaked in early 2018, increasing by 71 %, 62 % and 56 % compared with prices in mid-2016 for FOB China material at 85 %, 86 %

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and 87 % Al_2O_3, respectively (as quoted by Asian Metal). After some falls, prices rose again in early-2019 following sudden environmental shutdowns in the Shanxi Province. This time, prices saw a smaller increase but, by July 2019, remained at 56 %, 36 % and 37 % above the mid-2016 price at USD 333/t, USD 400/t and USD 362/t, respectively.

Alumina has not been immune to the effect of enforcement of environmental legislation, but the supply is from a much wider range of sources and China has less influence on world supply and demand. During early 2019, prices for alumina were still suffering from the perfect storm of 2018, with the forced, partial closure of Alunorte in Brazil, threat of US sanctions against Rusal, and a strike in Australia influencing spot prices. All of those threats have since dissipated and alumina index prices have now returned to values seen before the issues of 2018.

In China, there has been more recent disruption to supplies of feedstock of calcined alumina as the Xinfa Group, one of China's largest aluminium smelters, was forced to close all production lines at its 2,8 Mt/a alumina refinery in Jiaokou, Shanxi, in May 2019. This followed state-run CCTV reports of a Shanxi unit of Xinfa dumping red mud (a toxic by-product of the process that refines alumina from bauxite) in Xiaoyi City. The resulting environmental shutdowns were so extreme that all bauxite mines were closed and there was a period of no raw material bauxite availability for any use in Shanxi Province.

All the industry's rotary kilns in the Xiaoyi area were also closed and it was very difficult to get +85 % grade bauxite in China. FastMarkets reports that prices for white fused alumina (CIF Europe) increased by 60 % between their low in mid-2016 and peak in March 2018; by June 2019 prices remained 40 % above the previous low at USD 906/t. Meanwhile, prices for calcined alumina (FOB, refinery, 99 % Al_2O_3) increased by just 10 % between their mid-2016 low and February 2018 peak but have continued to increase and, by June 2019, were 16 % higher than the previous low at USD 800/t.

There are conflicting reports that the only remaining mine in the Xiaoyi area supplying bauxite suitable for calcining will soon close due to exhaustion of reserves and it is unclear whether a new mine has received required permissions to open.

Magnesium compounds

Refractories provide by far the largest market for magnesia, accounting for nearly 60 % of total consumption. Dead Burned Magnesia (DBM) is almost exclusively used in this application, used in both refractory bricks and monolithics because of its high resistance to basic slags, and high strength to withstand mechanical wear and abrasion in hot environments.

Fused Magnesia (FM) is also added to refractories such as magnesia-carbon bricks and can significantly enhance their performance and durability, due to FM's high specific gravity and large crystal size.

Refractory-grade FM is used in refractories for high-wear areas in steelmaking such as in basic oxygen and electric arc furnaces, converters and ladles. Refractories are also the largest application for FM.

The main magnesia-producing region is within Liaoning province, split between two hubs – Dashiqiao in Yingkou, and Haicheng in Anshan. Mining of magnesite and production of magnesia in both has been affected severely by a combination of very limited provision of explosives for mining and environmental inspections by the government. This has led to plant closures and the interruption of magnesite ore extraction and thus feedstock to DBM, FM, and Caustic Calcined Magnesia (CCM) plants.

Robust Chinese government anti-pollution measures from early 2017 prompted the closure of many magnesia calcination and fusion plants. This led to a sudden reduction in supplies and concern over the future of China's magnesium compounds supply chain. By late 2017, supply shortages had become severe.

DBM underwent significant price increases in early 2018, with prices for the highest grades seeing considerable price hikes. Prices for lower grade lump DBM, FOB China (as reported by FastMarkets) increased by 127 % (90 % MgO) and 131 % (92 % MgO) between mid-2017 and February 2018. Meanwhile, prices for higher grades grew by as much as 249 % (94,5 % MgO) and 291 % (97,5 % MgO) between mid-2017 and a peak in March 2018.

Prices have since fallen back as Chinese capacity reopened but, by July 2019, prices for these four grades remained 53 %, 56 %, 163 % and 145 % higher than the mid-2017 price.

Raw material prices easing, but China's environmental stance is unwavering

Price rises have slowed though H2 2018 and H1 2019 and in some cases have reversed, but prices for most of the refractory raw materials remain far higher than they were in the mid-2010s. By mid-2019, most of the temporarily closed capacity had reopened, but China has by no means finished with its environmental improvements.

China is expected to continue its programme of environmental inspections and the closure of plants that fail to meet standards across all industrial sectors, especially in the lead-up to 2021 – the year which marks the first of China's "two centenary goals" which represent the 100th anniversaries of both the CCP and the People's Republic of China – goals which were made by the 18th Party Congress in 2012, the same Party Congress that saw Xi Jinping assume his leadership position. The Ministry of Environmental Protection has recently stated that environmental protection "would only be strengthened with the deepening of the reform and would not be weakened".

Roskill's research in China suggests that the government believes environmental protection not to be at odds with economic development. In fact, a large number of Chinese producers are now reporting higher profits, especially the loss-making State-Owned Enterprises (SOEs). Future closures could probably have a lesser impact on mineral production levels (since most of the main manufacturing hubs have already undergone major overhauls) and have a quicker recovery time but, as overcapacity in China is taken out of the market, such situations could have more of an effect on global pricing.

Limited steel growth and falling refractory consumption

In addition to the raw material price squeeze, China's weakening scenario for steel is having a detrimental affect on total refractory demand. Roskill's in-house forecasts expect Chinese crude steel production to remain flat between 2019–2021 at around 975 Mt before declining by 0,6 % yearly to 2029, by which time output could drop to below 930 Mt. Meanwhile, some very limited recovery in the traditional markets of Europe, the USA and Japan, combined with strong growth in emerging markets such as India, could bolster global steel growth over the next decade; even so, global steel is expected to see growth of just 0,8 % yearly between 2019–2029, resulting in a flat forecast for concomitant global refractory output. At the same time, the Chinese steel industry continues to reduce its specific consumption of refractories with the closure of older steel-making operations and the opening of newer, more efficient technologies. China's refractory consumption per tonne of steel has dropped rapidly in recent decades and is now believed to be not far behind that of the global average.

Future trends in the refractories market

China's ability to dominate raw material prices may be a given but the next decade will continue to see the erosion of this dominance in terms of refractory market share and competitiveness.

Rising production costs in China mean that Chinese refractories, which have long been some of the least expensive on the market, are now closing the gap with more traditional producers. It is likely that other countries will become more involved, with India being the obvious first place to look as its growing steel production (at odds with steel trends in much of the rest of the world) requires an increasing consumption of refractories.

Although India's crude steel output is still small compared to that of China, at a forecast 112 Mt in 2019, growing domestic demand could result in around 6,0 % yearly of Indian crude steel growth between 2019–2029, putting it at more than 200 Mt of production by the end of the next decade. The country is also believed to be behind China in terms of its specific consumption rates for refractories (although these are falling), also helping to increase refractory demand.

China's vast quantity of mineral resources and proximity to market means it will remain the largest supplier of most raw materials for refractory manufacture, at least in the coming years.

Unless large amounts of material can be found in locations such as Africa or other parts of Asia, where production costs can be competitive with those of China, the importance of China's position is unlikely to diminish greatly.

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