Recycling refractories

Mike O'Driscoll* discusses how the recycling of refractories is entering a new era, with the rise of secondary raw materials becoming a dominant factor.

The recycling of refractories has been around for at least three decades, although it has only been in the last few years that the sector has witnessed increased commercial activity.

The primary driver has been the gathering momentum of a zero waste culture across the spectrum of industrial manufacturers, which include refractory users such as steel, non-ferrous metal, cement, and glass plants.

This trend not only helps to find a much needed, environmentally-friendly solution for spent refractories, but also helps to conserve mineral resources, energy consumption, and the overall cost of refractory production, as well as minimising the expense of landfill costs for end users.

The movement has received an additional boost from the development of relevant processing and quality control techniques, such as Laser Induced Breakdown Spectroscopy (LIBS), and in Europe from the much-lauded circular economy promotion driven by the European Commission through a variety of initiatives.

The upshot is that waste refractories will be just one of a range of secondary raw material resources– along with, for example, steel slag, fly ash, waste water, glass, paper, plasterboard, and red mud – from which the recycling of minerals hosted by these industrial wastes are to play a much more significant role in the future of the industrial minerals trade. The era of secondary raw material (SRM) supply is upon us ***(Fig. 1)***.

The industrial minerals market

In spite of declining specific refractory consumption (10-15kg/t steel; 3kg/t non-ferrous metal; 1kg/t cement; 4kg/t glass), around 35 million tonnes per year of refractory raw materials are consumed to make refractories worldwide.

That equates to a lot of mineral deposit exploration, development, mining, processing, and trading by mineral suppliers, and a lot of sourcing, buying, and logistics activity by refractory raw material purchasers.

Research by IMFORMED has shown that refractories ranks 10th out of 26 leading markets for industrial minerals, consuming as many as 24 different industrial minerals.

Certain key refractory minerals, such as andalusite, bauxite, fused alumina, graphite, dead burned and fused magnesia, silicon carbide and zircon, have experienced and continue to experience supply chain issues.

These issues include: Limited development of commercial scale resources; overreliance on leading sources, which have local issues that impact supply (China in particular, which is responsible for 40-90% of refractory mineral supply to global users); inconsistent quality and supply availability; and pricing and logistics issues. Such factors are a nightmare for refractory raw material purchasers ***(Fig. 2)***.

Refractory mineral purchasers are therefore seeking alternative raw material sources. With the rapidly evolving refractories recycling sector, it will soon become the 'new normal' for refractory mineral purchasers to be offered a menu of their mineral requirements which will comprise two distinct and competitive refractory mineral sourcing options: Primary and secondary raw materials (SRM).

While it is true that processing spent refractories demands certain processing and sorting requirements that are not necessary for mainstream primary mineral processing, it is clear that in recent years these challenges have been increasingly met.

Certain mineral processing companies have now developed a niche in mineral recycling, and in particular, processing refractory minerals from spent refractories.

Such companies include: DEREF, Italy; Harsco Metals & Minerals, UK REF Minerals, Latvia; Refra-System, Hungary; TYMO Engineering, Germany; Valoref, France; LKAB Minerals, UK; Mineralen Kollée, Netherlands; Horn, Germany.

This is expected to be a growing trend, with more players emerging in the near future. There is also likely to be more

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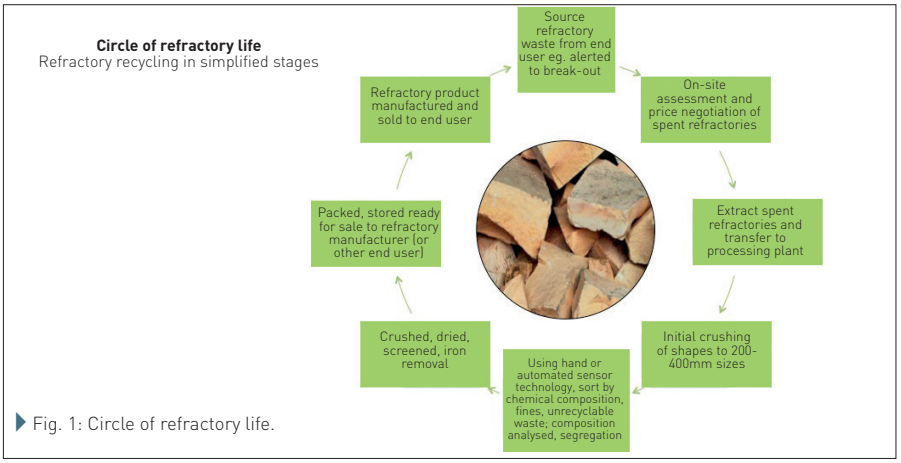

Fig. 1: Circle of refractory life.

Refractory classification	Industrial mineral (incl. synthetic)	Main chemical component	Primary source country
BASIC	Dead burned magnesia	85-99.8% MgO	China
	Fused nagnesia	97-99.8% MgO	China
	Dead burned dolomite	56-62% MgO, 36-40% CaO	USA
	Chromite	>46% Cr_2O_3	South Africa
	Sintered/fused spinel	66-80% Al_2O_3, 21-33% MgO	China
	Olivine	40-50% MgO, 34-45% SiO_2	Norway
ACIDIC	Calcined alumina	>99.5% Al_2O_3	China
High alumina	Fused alumina	94-99.5% Al_2O_3	China
	Calcined bauxite	85-88% Al_2O_3	China
	Sintered/fused mullite	40-75% Al_2O_3	USA
Low alumina	Andalusite, sillimanite, kyanite	60-65% Al_2O_3	South Africa
	Refractory clays	20-45% Al_2O_3	China
	Pyrophyllite	20-30% Al_2O_3	South Korea
Silica	Quartzite, silica sand	>97% SiO_2	Regional
	Fused silica	>99.8% SiO_2	USA
SPECIALISED	Zircon	66% ZrO_2+HfO_2	Australia
	Zirconia	>99% ZrO_2	China
	Silicon carbide	>93% SiC	China
	Graphite	75-99% C	China
INSULATING	Diatomite	>75% SiO_2	USA
	Perlite	65-80% SiO_2	China
	Vermiculite	45% SiO_2	South Africa

▲ Fig. 2: Refractory mineral summary table.

attention given to recycling refractories by the leading refractory manufacturers and end users.

Future use of SRMs

Steel producers are already turning their attention to refractory recycling. For example, Italy's Acciai Speciali Terni has teamed up with Deref to develop a zero waste strategy in recycling refractories and slag. However, it remains a case of 'early days'.

In his UNITECR 2015 presentation, Melvyn Bradley, Technical Director of LKAB Minerals, UK, acknowledged that despite LKAB's involvement in the refractory recycling market for many years (formerly as Minelco Minerals with Richmond Refractories): "Customer feedback has highlighted the need to improve the quality of the recycled refractory material, meaning investment in more advanced processing equipment and further development work on the use of reclaim material in the finished product."

In general, refractory SRM now appear to be more widely accepted in the refractories industry than previously. Europe is ahead of the pack globally, although Asia and North America are starting to pick up the baton.

Precise figures for refractory SRM, or refractory 'recyclate' are hard to ascertain, and published figures vary.

Where refractory SRM is likely to find a major market is in refractory products that have less stringent performance requirements, but where price remains a significant factor.

Typical waste refractories that can be recycled include firebrick, mid-alumina brick, bauxite brick, alumina-carbon, alumina-magnesia and magnesia-carbon bricks.

While the use of recycled aggregate in mag-carbon bricks is now common practice, according to Bradley the level of free metals remaining from anti-oxidant additions is key to preventing quality issues with new bricks.

Typical applications for alumino-silicate SRM include medium range castables and precast shapes. Recycled alumina-mag and mag-carbon can be used for tundish spray and furnace gunning repair products.

Other potential uses of refractory SRM include alumina-silicate SRM as a bauxite replacement in secondary ladle treatment, and mag-carbon SRM used as a slag conditioner in EAF.

In addition to providing SRM for refractory manufacture, spent refractories can become raw materials for powder coating applications, metallurgical additives, slag conditioners and feedstock for cement.

Refractory recycling outlook

There is no doubt that refractory recycling is going to see an increase in attention and activity. Owing to the potential large volumes of refractories for recycling and the fact that end users and refractory manufacturers are unlikely to invest in their own recycling plants, it is expected that an increasing number of refractory recycling processors will enter the market in the near future.

Chief among the trends and developments of this growing sector will be the evolution of a new supply chain of refractory SRM which will usher in new players whose roles will include waste refractory sourcing, recycling, processing/sorting equipment supply, logistics, marketing and purchasing.

Key trends to monitor:

- More and improved automation systems, particularly in refractory waste sorting;
- Development of mobile sorting systems;
- Research in refractory additives, such as microsilica, to improve the performance of products based on refractory SRM;
- Development of pelletisation of refractory SRM fines for use in other applications, such as slag conditioning;
- Development of new refractory formulations to enhance/ease their successful recyclability;
- Increased establishment of long term strategic alliances and partnerships between sources of spent refractories (end users), refractory recyclers and refractory manufacturers in both sourcing waste refractories and buying refractory SRM;
- Education of refractory end users (eg. steel producers) to positively engage in and recognise the benefits of refractory recycling, including reasonable prices for the sale of refractory waste;
- Clarification and universal (eg. EU) establishment of clear legislation, regulations, and licences regarding handling, processing and trade in refractory waste and refractory SRM. ■

IMFORMED is organising the Mineral Recycling Forum 2016, 14-15 March 2016, Rotterdam focusing on the SRM supply chain including refractories, and MagForum 2016, 9-11 May 2016, Vienna, focusing on magnesia supply and demand including refractories.

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