Review of Refractories Markets & Research – 2016

C. E. Semler

Globally, the major markets for refractories are iron and steel (~70 %) and cement (~10 %). The annual production of steel [1] and cement [2], by the World and China, since 2000, as a general indication of the market trend for refractories, is shown in Fig. 1–2, respectively. For both steel and cement production worldwide, and in China, it is seen that the upward trend of many years has slowed/flattened over the last 2–3 years.

Introduction

The world use of steelmaking capacity (Tab. 1) has declined since 2011, as shown below. Also it can be seen that for each year since 2011, the steelmaking capacity usage has been less during the 2nd half than in the 1st half of the year.

Tab. 1 Use of steelmaking capacity [%]

	Use of Steelmaking Capacity	
Year	1st Half	2nd Half
2011	82,4%	75,8%
2012	80,3	76,1
2013	79,2	74,8
2014	75,3	72
2015	71,9	67,7
2016	69,7	69,1

The recent production trends for the largest refractory markets (steel and cement) have certainly been a contributing factor to the revenue decline for the world's top three refractory companies, according to their published reports, as shown in Tab. 2.

Because China is by far the world's largest producer of steel and refractories, it is interesting to look at the correlation in their annual production of steel [1] and refractories [3] since 2000 (Fig. 3). It is seen that the refractory production increased rapidly from 2000 to 2007 (+185 %), in parallel with the rapid increase in steel production. But since 2007 the annual refractory production trend flattened, and varied (+ and -), in the range 25 to 29 Mt, while the annual steel production continued to increase significantly, until 2013. Since 2013, the increase in steel production in China has slowed/flattened, in the range 800–823 Mt, and refractory production has declined.

Charles E. Semler
Refractories Consultant
Phoenix, Arizona
USA

E-mail: CESemler@aol.com

Tab. 2 Revenue of the largest refractoriy producers

Revenue [Million]	1st Half 2015	1st Half 2016	Change [%]
Vesuvius*	702,6 GBP	668,3 GBP	-4,9
RHI-AG**	902 EUR	830,2 EUR	-8
Magnesita	537 USD	487 USD	-9

* Vesuvius CEO – Financial performance in 2016 is better than 2nd half 2015. Steel and foundry markets will stay relatively weak through 2016.

** RHI-AG CEO – Tons sold was up 3 %, but revenue in 2016 was down due to weaker business in South America, Europe, and China.

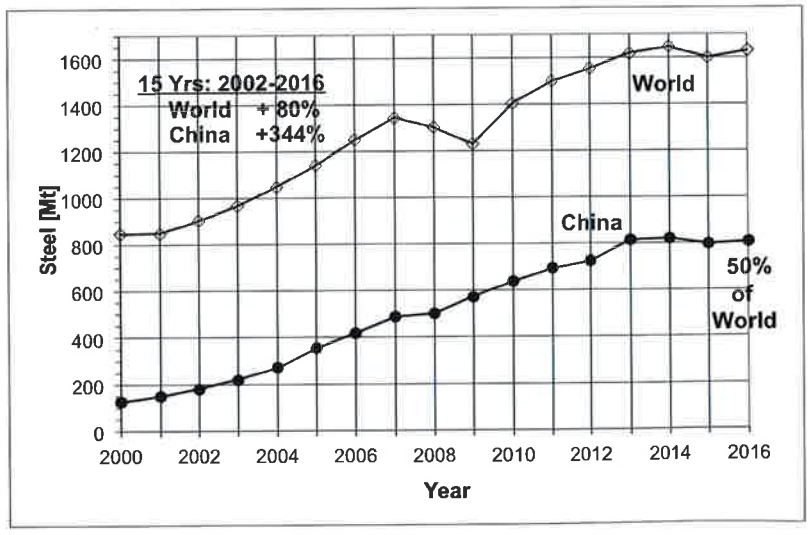

Fig. 1 Annual production of steel by the World and China since 2000 [1]

As shown in Fig. 4, the steel production in India has increased each year, from 2000 to 2015, rising 228 %, and surpassing the United States in 2015, to become the World's third largest steel producer, behind #2 Japan and #1 China. Likewise, except for 2013, the refractory production in India has increased each year from 2000 to 2015, which is 217 %, to meet the needs of the steel industry. To document the relative comparison of scale, it should be noted that the refractory production by China in 2015

(26,15 Mt) was 19x and 25x more than India and Japan, respectively.

Refractory research activities and trends

It has long been known that the refractories industry needs to maintain good communications with their customers. It is important to know and monitor the refractory problems and needs of the customers, to enable the best efforts in directing contacts and R&D on the most pertinent topics, that will yield practical/technical advances, field successes, and good financial returns. A recent presentation by Arcelor-Mittal Steel/CA [5] provided the following advice/comments for the refractories industry:

- The basic concern of steel technologists is, "What types of refractories will make my job easier, and prevent failure 100 % of the time"?
- A monitoring system is needed that will give ongoing refractory wear/consumption info and a projection of the refractory life.
- Monolithics are needed that will set at extremely cold temperatures, like –40 °C.
- Steelmaking involves thermal cycling which shocks/cracks refractories, so refractories are needed that develop microcracks that don't propagate.
- Better refractory qualification tests are needed that will predict refractory service life.
- Refractories are needed that reduce the size/quantity of inclusions in steel, and hopefully can play a role in removing inclusions.
- Some of our greatest successes for refractories have involved co-engineering of products with other companies, including people with diverse backgrounds/experience. How can this become the norm rather than the exception?

As a general indication of the refractory research topics of most interest in recent years, in the Asian-Pacific Region, several published sources were reviewed, including Annual Research Reports of Krosaki-Harima and Shinagawa Refractory companies, in Japan, China's Refractories (quarterly journal), and the Proceedings of the India Refractory Makers Association (IRMA) International Refractories Conference (IREFCON). For Japan and China, the popular research topics, as indicated by publications in 2011 and 2015, are shown in Tab. 3. This general overview indicates

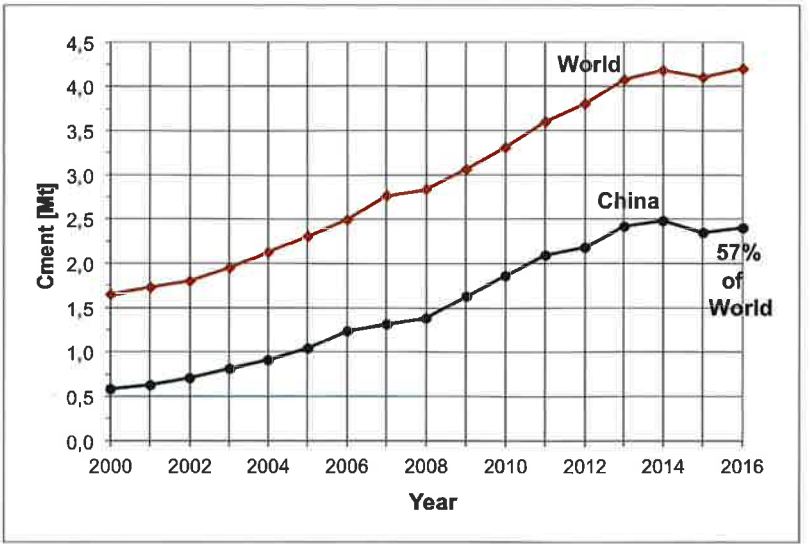

Fig. 2 Annual production of cement by the World and China since 2000 [2]

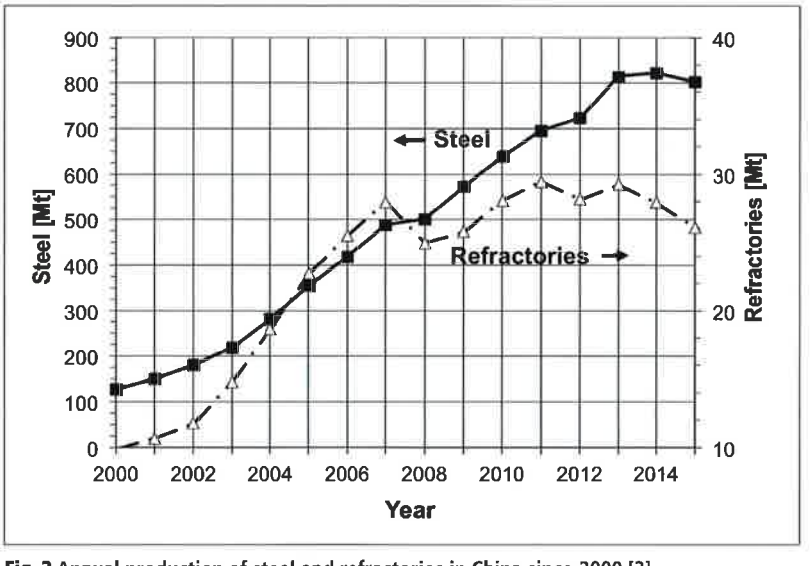

Fig. 3 Annual production of steel and refractories in China since 2000 [3]

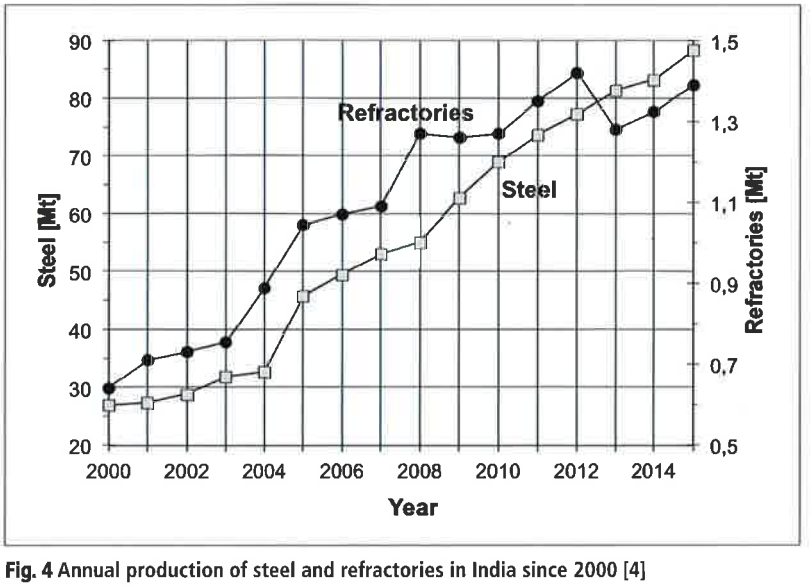

Fig. 4 Annual production of steel and refractories in India since 2000 [4]

Tab. 3 Snapshot of refractory research topics in Japan (papers in corporate research reports) and China (published papers), according to published papers in 2011 and 2015

	Japan	China	Japan	China	
Refractory Topics	2011	2011	2015	2015	Total
Iron and Steel/Other Applications	10	10	5	6	31
Monolithic Refractories	6	3	6	6	21
Carbon-Containing Refractories	4	1	2	1	8
Non-Oxide Refractories	1	1	0	8	10
Testing and Fundamental	83	9	12	32	
Raw Materials	3	4	1	3	11
Energy/Insulation	3	1	2	3	9
Recycling	0	0	1	1	2

Tab. 4 Summary of the refractory topics discussed at IREFCON, since 2012

Refractory Topics	2012	2014	2016	Total
Iron and Steel Industry	14	13	12	39
Other Applications	7	4	3	14
Monolithic Refractories	10	17	6	33
Carbon-Containing Refractories	6	3	4	13
Non-Oxide Refractories	2	1	0	3
Testing and Fundamental	10	11	7	28
Raw Materials	11	8	11	30
Energy/Insulation	4	0	0	4
Recycling	0	0	0	0

that the generic topics of main interest in Japan and China, in the 2011–2015 time period were testing & fundamental principles (26 %), iron and steel and other applications (25 %), and monolithic refractories (17 %).

IRMA's IREFCON is a biannual refractories conference that attracts a multinational audience and speakers, hence the program reflects the refractories research activities/interests in India, along with some influence of the international participants. A summary of the generic refractory topics discussed at IREFCON in 2012, 2014, and 2016 is shown in Tab. 2. The totals indicate that the most popular generic topics discussed at IREFCON since 2012, are the iron and steel industry (24 %), monolithic refractories (20 %), raw materials (18 %), and testing and fundamental principles (17 %). The same as for Japan and China, the reason for the high interest in the iron and steel industry is obvious, because it is by far the major market/user of refractories worldwide.

The annual reports of the major refractory companies, Vesuvius and RHI-AG, provided the following information about their R&D efforts in 2015:

- Vesuvius listed the following R&D topics for 2015: robotic tundish spray lining systems, semi-automatic dry-vibratable installation (fast), low-carbon bricks and low-carbon/hydrogen tundish linings, inert tundish barrier products, and products for Al-melting and -holding furnaces. The innovations reported by Vesuvius for 2015 included: cold-start technology, swirling sub-entry nozzles, and edge port sub-entry nozzles.
- RHI funding for R&D in 2015 was 23,4 EUR million – 15 % was for basic research, 40 % for new products and production processes, 20 % for existing products/processes, and 25 % for environmental protection and improved energy efficiency. R&D topics listed for emphasis by RHI were: develop special ceramics, NDT for quality control and optimized production, use of recycled materials, including new methods, use of new materials and combinations of materials, high temperature insulating materials, develop environmentally-friendly binders, and simulation and modeling methods.

Never-ending advancement of technology

Comments by Walt Disney [6], founder of Disney Co., are directly applicable to the fact that progress never stops. Disney said, "We keep moving forward – opening doors and doing things, because we are curious. And curiosity keeps leading us down new paths. We are always exploring and experimenting. We call it "Imagineering" – the blending of creative imagination with technical know-how".

In 2010, D. Michael of HWI [7] presented a paper at ALAFAR, which included the following comments about innovation in the refractories industry:

- Companies must innovate to survive in a global economy.
- There are various types of discoveries/innovations, such as "Breakthroughs", like MgO–C bricks, A–M–C bricks for ladles, better dispersants, low-cement castables (LCC), etc. And "incremental innovations", such as adding organic fibers to castables, improved cements, better dispersants, precast shapes, to name a few.
- To promote innovation, it is necessary to have good people to offer good/creative ideas for critical review and action.
- Today, if you are not promoting creative thinking, and innovating, you are moving backwards.

Examples of refractory advances

Over the decades, there has been continuous improvement of refractories, involving major/minor advances in the associated fundamental science and technology, modeling, testing, practical applications, etc. Each year there are countless published examples of these advances that benefit the refractory users. Two successful projects are reviewed below as representative examples of how refractory R&D provided significant improvements at steel companies:

1. BOF taphole sleeve life at Tata Steel/IN was increased from 102 heats, for the conventional sleeve product, to 130 heats (+27 %) for a novel hybrid sleeve [8]. Three MgO–C sleeve compositions were prepared for comparative evaluation – A, spall resistant; B, Hi-strength, and C, hybrid combination of A and B. Their compositions and properties are shown in Tab. 5.

This example illustrates the known fact that for refractories, that "stronger products are

not always better", as the best performing sleeve composition had the lowest hot strength of the three trial compositions.

2. The service life of the sidewall castable in steel ladles was increased at Nippon Steel Sumitomo Metals Corp./JP. The performance of ladle refractories is a significant factor in steel plants, because they account for about 20 % of the refractory costs. The durability of sidewall castable is a determining factor in the performance and repair of steel ladles. Spalling due to slag penetration is a major factor in the degradation of sidewall castable. A study by NSSMC resulted in development of a stronger, denser castable (92 % Al_2O_3, 6 % MgO), which exhibited a 23 % lower damage rate in ladle service. A comparison of the previous (conventional) and improved sidewall castables is shown in Tab. 6.

Tab. 5 Variation of tap hole compositions

	A	B	C
MgO / C	88 / 7	84 / 9	89 / 6,5
1400 °C Bending Strength (MOR) [MPa]	14	22	11
Service Life [heats]	121	124	130

Tab. 6 Improvement of ladle sidewall castables

	Conventional	Improved
Bending Strength after 1500 °C [MPa]	24	27,3
Apparent Porosity [%]	19,8	17,9
Water Added [%]	5,8 %	4,2 %

Concluding comments

1. Recent observations about the refractories industry provide an indication of the relative status. McCormick (10) stated that "The refractories industry remains under pressure, with no immediate signs of an upturn in the market". And a Vice-President of Zhejiang Zili Corp., Ltd., China said, "We are not at the bottom of the trough, but it is close".
2. The RHI 2015 Annual Report reported that by directive of the Chinese government, local refractories companies are considering options for mergers. The goal is to have five refractories companies of international size. This will pressure refractory companies outside China to merge.
3. History has shown that refractory technology will continue to advance. Innovation never ends.
4. Research will continue to focus on iron and steel refractories, such as carbon-containing and monolithic products. Emphasis needs to be continued and

increased on the role of refractories in making clean steel, including filtration, and enhanced ladle operations.

5. There is a need to further the understanding and utilization of engineered microstructures in refractories, that could result in significant improvements in properties and performance.
6. The need continues for new and improved tests, and especially tests at high temperature and/or under simulated service conditions, to evaluate and compare refractories, and permit a prediction or projection of expected service life. Modeling, and thermochemical software, can and will play an important role in the understanding and development of improved refractories.
7. More research should be focused on refractory products that save energy, and because the long-term supply of raw materials is limited, more study is needed on recycling/re-use of used refractory materials.
8. 3D-printing (Additive Manufacturing) needs to be exploited for refractories, because the opportunities are unlimited, and especially the potential for development of novel materials with creative, unique structures.

References

[1] World Steel Association, www.worldsteel.org, Steel Production

[2] United States Geological Survey, www.usgs.gov, Cement Production

[3] China's Refractories (Quarterly Journal), and Personal Communications

[4] India Refractory Makers Association (IRMA)

[5] Mazzetti-Succi, V.; Vert, T.: Arcelor-Mittal-Canada. Steelmaking Refractories – 2030 Dream Scenario, Proceedings, St. Louis Refractories Symposium, 182–193, 2016

[6] Walt Disney Quotes: www.brainyquotes.com/quotes/authors/w/walt_disney.html

[7] Michael, D.: Innovation and the Refractories Industry, ALAFAR Proceedings 2010, 1–7

[8] Singh, B.; Tagawa, S.; et al.: Improvements in BOF Refractory Practices at Tata Steel Ltd., Proceedings, IREFCON 2014, 222–226

[9] Takashima, S.; et al.: Improved Service Life of Steel Ladle Sidewall Castable, Taikabutsu Overseas **36** (2016) [2] 108

[10] McCormick, M.: Industrial Minerals (2016) [4]