

STEEL MEETS REFRACTORY – A NEW PLATFORM FOR TECHNICAL EXCHANGE IN GERMANY

A. Buhr*, Almatis GmbH, Germany
P. Quirnbach, University Koblenz-Landau, Germany
J. Pischke, Salzgitter Flachstahl GmbH, Germany
E. Steinle, Deutsche Feuerfest Industrie e.V., Germany

ABSTRACT

The dialogue and networking between experts from the refractories and the steel industries is essential for successful development of new refractory concepts, products, and solutions. It becomes even more relevant with the upcoming challenges when transforming the carbon-intensive steel making process to carbon neutrality. New technologies in steel making require adjustments of refractories, and refractories have an influence on the process performance in multiple ways, both technically and economically. This paper discusses the long tradition of technical cooperation between the steel and refractories industries in Germany and how the new platform “Steel Meets Refractory” continues this important technical exchange between experts of both industries.

HISTORICAL DEVELOPMENT

Refractories are fundamental for the steel making process as linings for furnaces and treatment and transport vessels. Often they also fulfill a functional role in order to perform metallurgical processes in principle such as purging plugs in the bottom of steel ladles. When looking back a couple of decades it becomes clear that the strategic role of refractories for steel making companies has undergone changes because of significant developments in the steel making technology such as the transfer from open heart furnaces to oxygen blowing converters,

the continuous casting of steel, and the introduction of secondary metallurgy in the steel ladle. As consequence two major trends took place with regard to refractories: a drastic reduction of specific refractory consumption in steel making from 50 to less than 10 kg per ton of steel (fig. 1) and new higher performance and quality refractory materials which can cope with the much higher challenges of the modern steel making processes.

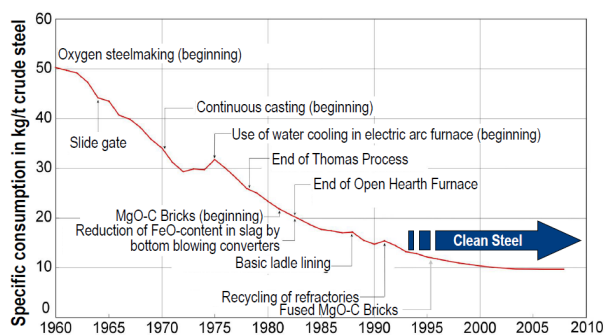


Fig. 1. Specific refractory consumption in steel making and technology changes^[1].

In the 1960 and 1970s many steel companies had own refractory manufacturing plants or companies in order to secure supply and consequently they also had dedicated refractory departments. The German Steel Association VDEh had a refractory committee, where refractory experts from the steel companies regularly met and discussed trends, technical challenges or experiences with testing refractories. The following topics were discussed and published just to give a

This UNITECR 2022 paper is an open access article under the terms of the [Creative Commons Attribution License, CC-BY 4.0, which permits](https://creativecommons.org/licenses/by/4.0/) use, distribution, and reproduction in any medium, provided the original work is properly cited.

few examples: Experiences with different brick materials for BOF lining^[2]; Development of refractories testing to provide information on the suitability of refractories for industrial applications^[3]; Wear characteristics of blast furnace runner mixes^[4]; Trend of refractories in the European steel industry^[5]; Refractory lining for steel ladles^[6].

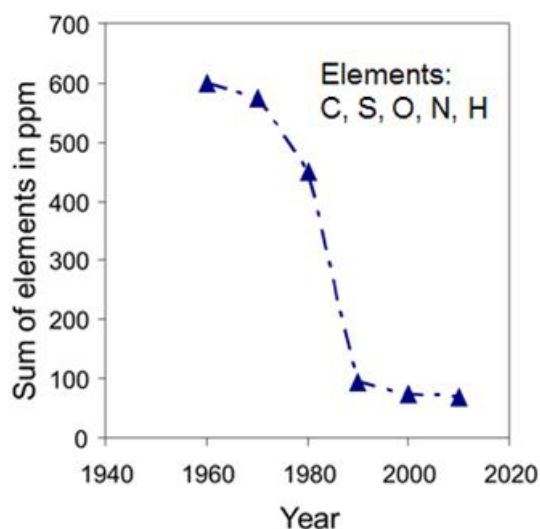


Fig. 2. Achievable contents after secondary metallurgical treatment between 1960 and 2010^[7].

Starting in the 1970s and then very intensively in the 1980s the above mentioned steel technology changes (fig. 2) led to the introduction and development of new refractories and a refocus of many steel companies on their core business and away from own refractory production. New refractories development was driven by companies focusing on that business. As a consequence, resources in the refractories departments in many steel works were reduced and some laboratories closed. This led to a situation, that a low participation and contribution of new results and

developments was jeopardizing the future of the refractory committee of the German steel association. Therefore it was decided in 1993 to include refractory suppliers as committee members. In the following years this proved a very successful approach to sustain and further develop this platform for technical exchange and networking between experts from both sides, suppliers and users of refractories for steel making. Examples for published output are papers on requirements on refractories for ladle metallurgy^[8], refractories and raw materials situation for steel production in Europe^[9], trends in clean steel technology and refractories engineering^[10], and the committee's perspective on various refractory products and requirements in steel applications^[11].

In 2017, VDEh decided to stop all technical committee work of the association including the refractories committee.

NEW PLATFORM "STEELS MEETS REFRACTORY"

The value of such technical exchange platform was very obvious to stake holders from the refractories and the steel industries. Although refractories are essential for the steel making process, they are often not very much in focus in the management of the entire steel making process. Refractories represent less than 2% of cost in the steel making process. And only very few engineers in the steel industry do have strictly refractories dedicated roles in their organizations.

Therefore it is important for those engineers being in charge of refractories having a network of technical experts also outside their organization. They can exchange experiences, get input and develop new ideas and approaches to address and

solve technical challenges in the use of refractories in various applications. This can never be a “lone-fighter-show” as the young Andus Buhr was told by his supervisor Manfred Koltermann right away when starting his career in the Dortmund steelworks in 1990.

Also for the engineers in the refractory industry it is very important having technically competent partners at their steel customers in order to develop a thorough understanding of specific requirements for improving existing and developing new refractory products and solutions. Refractories do influence the process costs in steel making beyond the cost for material and installation, e.g. through impact on the steel quality, yield in production, and energy saving or losses during the process.

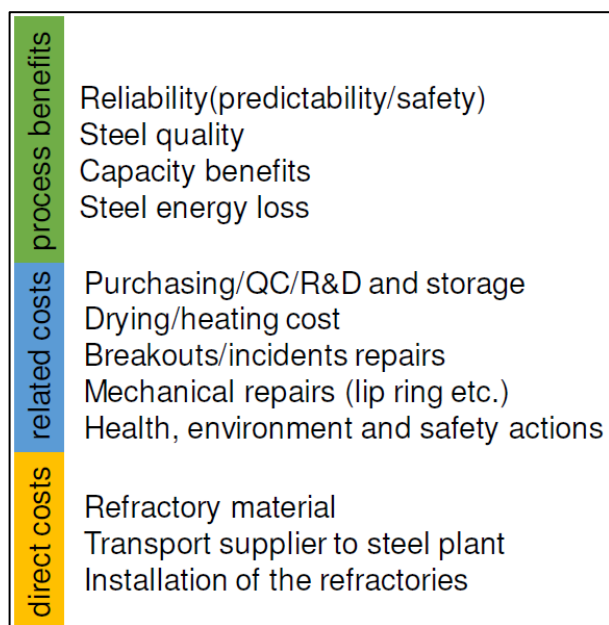


Fig. 3. Direct refractory cost (~30%), refractory related cost (~30%) and the process benefits influencing the Value in Use (~40%) [12].

These indirectly related refractory costs are higher than the direct ones and it can be both, economic gains or losses for the entire process (fig.3). This integrated approach to refractories is discussed in detail by Siebring et al.[12] and named “Value in Use” at Tata Steel IJmuiden.

In 2018, activities were started by key stake holders from the refractories and steel industries in Germany for establishing a new platform for regular technical exchange. A considerable share of German refractory manufacturing is located in Rhineland-Palatinate. And the European Centre for Refractories (ECREF) in Höhr-Grenzhausen supports the interests of the German and European refractory manufacturers to sustainably strengthen the global position of the refractories industry with coordinated and networked measures and programs in education/training, research, and innovation.

Through an initiative of the network of refractories experts within the ECREF, the German Refractory Association (GRA) in cooperation with the Ministry of Economics of the Federal State Rhineland-Palatinate have established in 2019 the “Steel Meets Refractory” meetings as industry dialogue format. At the first meeting, state secretary Daniela Schmitt highlighted the importance of dialogue and networking of experts in the value chain as an important factor for successful innovation and consequently investments, employment, and competitiveness. Therefore the Ministry is supporting the technical-scientific exchange between the steel and the refractories industries.

Under the patronage of the Ministry, the meetings take place twice a year in spring and autumn with invitations sent from the GRA to selected technical experts from their member companies and the steel industry in

Germany, Austria, and the Netherlands. Compliance is assured through a representative from the Ministry and a lawyer being present through the entire event and highlighting the guidelines at the start.

The following general thematic areas are covered in the meetings: 1) environmental, health, and safety (e.g. classification of refractory products), 2) specific actual technical problems and challenges (e.g. recycling of refractory products), 3) innovation (e.g. drying and heating of monolithic installations).

EXPERIENCES

Meeting format

So far, four meetings took place. The first one in August 2019 and prior to the Corona pandemic with physical presence in Koblenz and including a plant visit to GRA member Steuler-KCH GmbH at their plant in Höhr-Grenzhausen on the second day of meeting. The following three meetings were online events. Participation was around 50 people at each event with one third coming from the steel industry. With the experiences everybody gained over the past two years with the new online meeting tools, sharing of presentations but also having lively discussions afterwards worked astonishingly well. That was certainly supported through the existing relations and trust level between participants. Of course, the networking part is missing without a social event as a joint dinner and continued discussions in smaller groups afterwards. So the next meeting is planned as physical event again in spring 2022 if the pandemic situation hopefully allows it.

Green Deal and CO₂ reduction

Global climate protection and reduction of CO₂-emissions is a key challenge for energy intensive industries such as steel and refractories. The European Green Deal as decided by the European Commission means a CO₂-reduction by 55% in 2030 (when compared to 1990) and climate neutrality by 2050. An overview of steel production in Germany and Europe in relation to the climate targets and a review of coking coal production in Germany with regard to globalization and de-carbonization were given in the first meeting.

The roadmaps of seven steel companies towards carbon neutrality were briefly presented in the third meeting. Iron ore reduction with coal is inherently the major contributor of CO₂ emission in steel making. Replacing carbon by green hydrogen produced with renewable energy is therefore key element in all concepts towards carbon neutrality. With a share of about 60% of iron ore based steel manufacturing in EU 28 (incl. UK), the magnitude of transformation required in Europe is obvious.

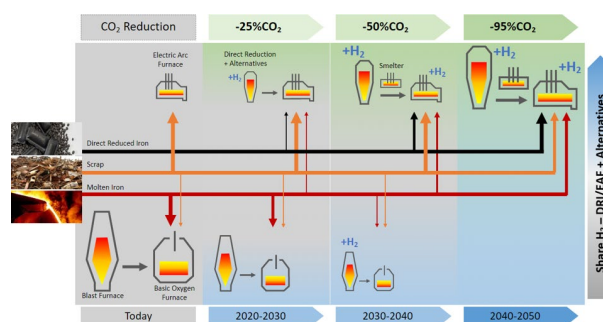


Fig. 4. Transformation from carbon to hydrogen based steel production^[13].

Although the concepts of steel companies show some differences in the technical approaches, they have one thing in common: these technology changes will have

an influence on processing conditions and consequently on the refractory linings. Direct reduction processes of iron ore are applied already since decades but their share in overall steel production was rather small so far. This will change dramatically in the future. Research is needed e.g. on the stability of refractories in hydrogen containing atmosphere and first activities have been started recently.

Refractories have an influence on the energy efficiency of steel making processes. Refractory materials with higher carbon content (including graphite) as refractory linings in the steel ladle side wall result in 10-20K higher temperature losses of the steel when compared to carbon-free linings. The cost for such temperature losses are in the range of the refractory lining cost of the steel ladle^[10]. Milos Blajs reported about the advantages of silica-sol bonded monolithic refractories with regard to shorter heating up procedures when compared to hydraulically bonded materials in the second meeting. And Johan Richaud provided other examples from refractory applications in continuous casting in the last meeting, concluding that it is important to consider this impact of refractories when performing life cycle analyses and not just the carbon footprint of a specific refractory product.

The climate road maps of the tile, ceramic, and lime industries and ways to decarbonize the German cement industry were presented during the last meeting, because the group was interested how other industries approach these challenges. A phasing out of blast furnace technology in the future provides an additional challenge for the cement industry where blast furnace slag is successfully used as low carbon clinker replacement.

Sustainability and recycling

Sustainability, circular economy and recycling of materials in order to secure and protect natural resources is another important element of the Green Deal. While steel can be considered a benchmark with regard to recycling, refractories recycling is so far only applied to some extent and not comparable with the level achieved in steel. One example are used BOF or EAF bricks being reworked into steel ladle bricks. It was presented and discussed in the second meeting, that regional value chains are essential for an economically successful approach to recycling. Besides close cooperation and trust between the business partners, also short supply chains are mandatory because long distance or intercontinental transport would erase all ecological gains and economic competitiveness from recycling.

This aspect was also discussed by Helge Jansen during his keynote lecture “Sustainable refractory concepts made in Germany” at the ICR[®] in Aachen 2021. If refractory recycling shall be extended in the steel industry, sustainability must become an additional factor when designing refractory linings.

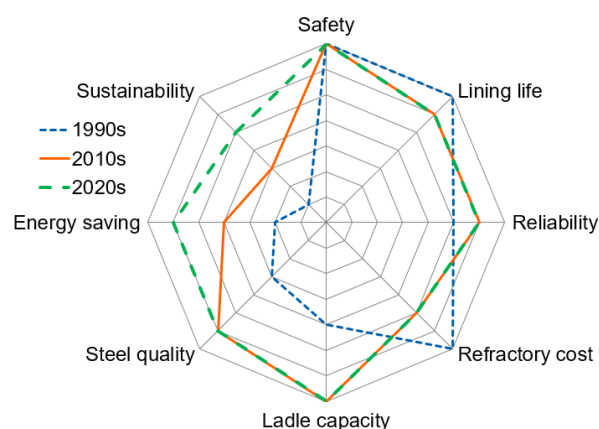


Fig. 5. Requirements for steel ladle lining.

Fig. 5 shows how requirements on the steel ladle lining have changed over the past 30 years.

Refractories classification and digitalization

The classification and labelling of refractory products and what is legally required versus the expectations for product information from the end users was intensively discussed during the second meeting. It became clear, that a mutual approach between suppliers and users of refractories might provide a better solution than only relying on legislation here, which in cases creates an enormous administrative effort without providing real value to the customer concerned. This was also recently discussed by Liefhebber et al.^[14].

The World Refractories Association WRA has a task force for developing a refractory exchange data standard. The main goal is to define and standardize data sets to exchange relevant data with customers and to also approach a higher level of automation in exchange. The intend is not the exchange of sensitive or confidential data of refractory suppliers, their customers and/or collaborating OEMs. During the discussion in the third meeting, the steel participants confirmed the relevance of this project because in the current situation too much administrative work is required by transferring relevant information (regarding the material itself but also logistics etc.) manually into ERP systems of the steel works. Steel engineers have confirmed their openness to collaboration for developing this standard by providing qualified feedback along the process.

OUTLOOK

The “Steel Meets Refractory” platform has proven its value already over

the four meetings during the past two years. The brief summary of topics addressed in this paper shows the complexity of refractory business in the steel making process and which challenges the industry is facing already in the near future. The raw material situation and a refocus on regional supply chains is another area which will be addressed in future. Successful solutions will require a close cooperation between suppliers and customers of refractories and a mutual effort of the entire industry. The dialogue and networking between experts in the industry plays an essential role in this long term journey.

ACKNOWLEDGEMENT

In the name of all participants, the authors express their gratefulness to the Ministry of Economics in the state of Rhineland-Palatinate for supporting “Steel Meets Refractory” and Thomas Kaczmarek with the German Refractory Association for organizing the events.

REFERENCES

1. Statistisches Jahrbuch der Stahlindustrie, www.stahl-online.de.
2. M. Hater, R. Klages, M. Koltermann, R. Schrott, “Erfahrungen mit verschiedenen Steinmaterialien bei der Ausmauerung von „LD-AC“ Konvertern“, *stahl und eisen* 90 (1970), no. 26, 1510-1515.
3. H. Schäfer, M. Koltermann, “Stand, Entwicklungsrichtungen und betriebliche Aussagefähigkeit der Prüftechnik feuerfester Stoffe“, *stahl und eisen* 94 (1974), no. 15, 657-664.
4. K.R. Hüsiger, M. Koltermann, “Ergebnisse von Untersuchungen des Verschleißverhaltens von Hochofenrinnenmassen mit einer halbtechnischen Versuchsanlage“, *stahl und*

eisen 97 (1977), no. 1, 23-28.

5. M. Koltermann, "Refractories from the European viewpoint – development and trend of refractories in the steel industry", Proceedings of the 1st International Conference on Refractories, Nov. 15-18, 1983, Tokyo, Japan, 63-83.

6. G. Klages, H.-D. Köhlau, M. Koltermann, H. Sperl, "State of the art of refractory linings for steel ladles in Germany", Proc. UNITECR'89, Anaheim CA, Nov. 1-4, 1989, 576-585.

7. R. Fandrich, B. Kleimt, H. Liebig, T. Pieper, F. Treppschuh, W. Urban, "Stand der Pfannenmetallurgie und aktuelle Trends (Status of secondary metallurgy and present trends)", stahl und eisen 131 (2011) no. 6/7, 75-89.

8. N. Bannenber, A. Buhr, "Anforderungen an das Feuerfestmaterial in der Pfannenmetallurgie", stahl und eisen 118 (1998), no. 10, 83-87.

9. J. Pischke, A. Baaske, D. Dübers, R. Fandrich, P. Quirnbach, L. Schöttler, "Current situation of refractories and their raw materials for steel production in Europe", ICR[®] Aachen 19-20 Sep. 2012, presentation at the dedicated raw materials session.

10. A. Buhr, R. Bruckhaus, R. Fandrich, "The steel industry in Germany – Trends in clean steel technology and refractory engineering", UNITECR'15 keynote lecture published in Refractories Worldforum 8 (2016), no. 1, 57-63.

11. A. Baaske, R. Fandrich, J. Pischke, P. Quirnbach, J. Rzepczyk, L. Schöttler, "Refractory Products – the TC Refractories Perspective", Refractories Worldforum 9, no. 2 (2017), 15-23.

12. R. Siebring, S. Sinnema, W. Tesselaar, "Bridging the gap between refractory supplier and the refractory user in the steel

plant → Real Value in Use", Refractories Worldforum 9 (2017), no. 3, 71-75.

13. L. Rebouillat, CESAREF project proposal, Nov. 2021.

14. J. Liefhebber, R. Siebring, H. Hoek, N. Mustacevic, "Impact of health and safety regulations on refractories buying and selection at Tata Steel IJmuiden", ICR[®] Aachen Sep 29-30, 2021, 31-34.