RHI Refractory Solutions - a Reliable Partner for the Ferroalloys Industry

Ch.Wenzl[1] and A. Spanring[1]

[1] RHI AG Vienna, Wienerbergstrasse 9, 1100 Vienna, Austria; christine.wenzl@rhi-ag.com

ABSTRACT

RHI has been serving the ferroalloys industry for many years and is well-known for its proven refractory solutions, combining high quality refractory materials and additional technical services. Excellent process knowledge and close collaboration with customers and well known OEMs help to detect further optimization potential in the areas of refractory selection, application and development of new materials. To achieve the necessary performance of a fully engineered furnace lining a proper installation is also very important with a strong focus on furnace integrity. A comprehensive approach which takes into account all these fields is required to guarantee economic and safe furnace operations. The present paper gives a general overview of recent developments, as well as application of engineering tools and their big advantage to integrate chemical and physical influences, implemented in a variety of furnaces in the world of the ferroalloys industry.

1 INTRODUCTION

Over the last years and decades the importance and production of ferroalloys industry has increased, due to its connection with (stainless) steel production, which is the main application area for ferroalloys [1]. In order to improve ferroalloy production processes, production routes and vessels have to be optimized continuously – refractory materials which are a decisive factor for furnace performance are one of the parameters in this optimization process. The main difference and also challenge in ferroalloys production compared to the production of base metals such as Cu, Pb and Zn, are the high temperatures involved in the production processes.

Therefore, adequate refractory linings have to be chosen in order to guarantee safe furnace operation and satisfactory furnace lifetime with short downtimes for repairs. In order to consider all these aspects, holistic refractory solutions are required: starting with proper material selection, functional lining concepts for the individual process and refractory engineering, and also taking into account a time-saving and safe installation methods. Furthermore, to guarantee even further improvement of the refractory products and hence production processes, post-mortem investigations of used refractory materials from production vessels help to understand the wear mechanisms and process challenges.

Considering the production processes of the various ferroalloys the production steps can be divided into ore preparation, reduction, refining and casting. These process stages include various pyrometallurgical vessels, each requiring different refractory products. Generally, a wide variety of refractory products is used, both formed and unformed products of both basic and non-basic materials, including different application methods (e.g., brick installation with/without mortar, prefabricated shaped geometries, castables, gunning materials, ramming materials).

The present article gives an overview of RHI's latest developments and technology improvements for the ferroalloy industry. The principal pyrometallurgical production vessels in ferroalloys industry, for example FeNi production (Figure 1) are:

- Rotary kiln (dryer, calciner)
- EAF (AC, DC)
- Refining vessels (ladle, converter)
- Launders and auxiliary equipment

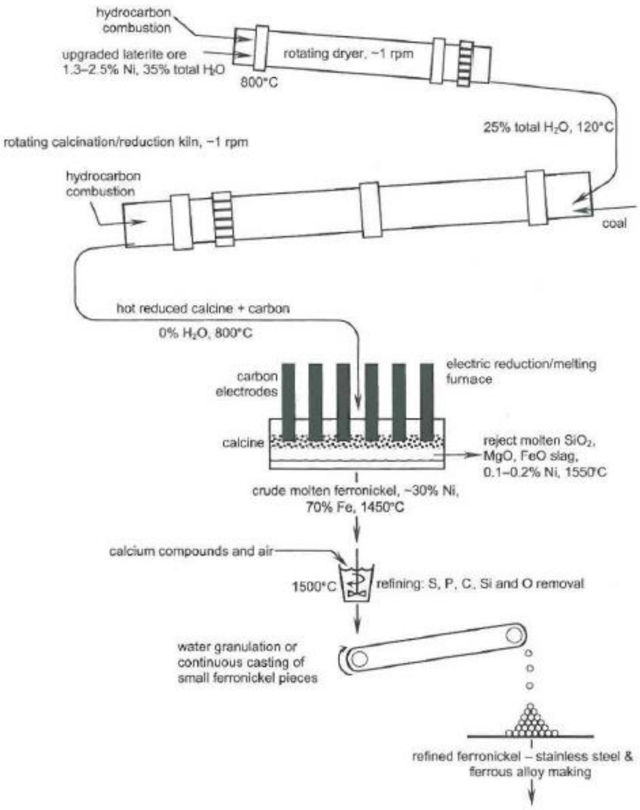

Figure 1: FeNi production route [2]

A special process route and vessel type is the production of Si, FeSi and FeMn where - due to the high temperatures implied and the high tendency for reactions with refractory oxides - carbon linings are used (Figure 2).

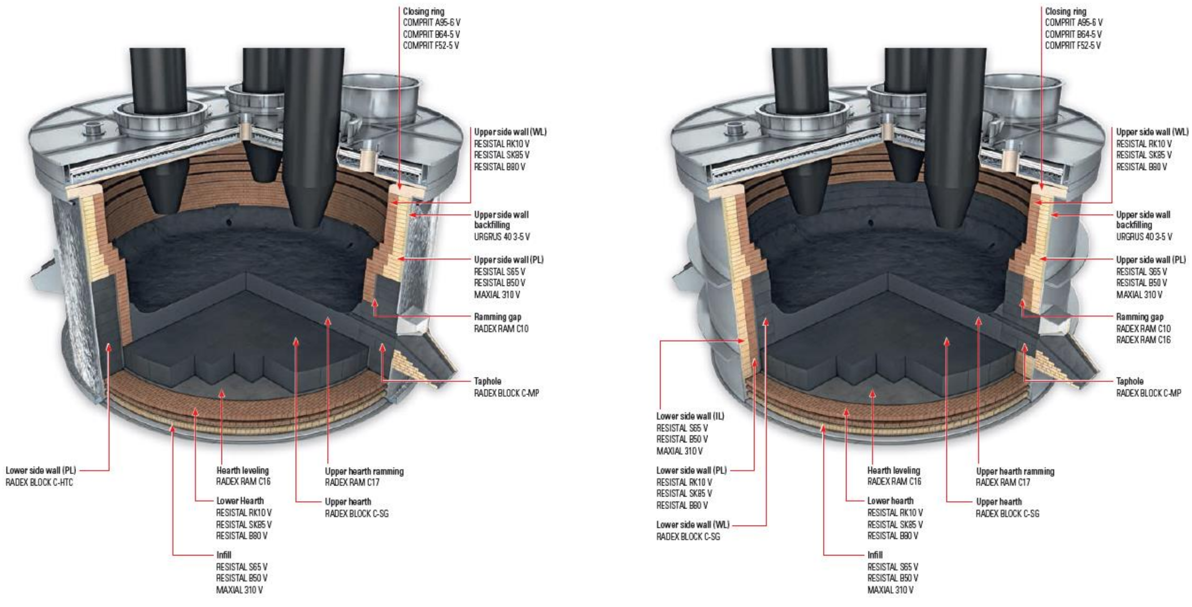

Figure 2: RHI carbon lining concepts (left: freeze lining concept, right: insulative lining concept)

When designing lining concepts, process knowledge is decisive in order to see parallels to other production routes and take advantage of experiences in other industries, learning from examples and adapting proven concepts to the specific production vessel. In case of ferroalloys production, regarding vessels and processes, some similarities can be found with steel industry, but also with vessels used in cement production. However, lining concepts can never be just a “copy/paste” version from other industries, as the specific features of every process have to be understood and considered. RHI’s refractory concepts for ferroalloys producers are industry-specific solutions, including longstanding knowledge of industry practice and experience in refractory materials, as well as internal experience and knowledge exchange between RHI's divisions.

2 NEW APPROACHES, TECHNOLOGIES AND PRODUCTS

In order to achieve efficient and safe furnace operations, comprehensive refractory lining concepts which take into account Furnace Integrity, i.e. the furnace as a holistic unit with many interacting sub-areas that cannot be changed independently, are required. Industry-specific refractory design also has to include a close collaboration between the refractory producer, namely Sales, Marketing and Research, and the ferroalloy producer. RHI's additional technical services, namely technical studies (e.g., wear studies for material suggestions) and after-sales services (e.g., post mortem investigations) allow reproducing and understanding customers' process conditions and gain more realistic insights.

Below, some new RHI technologies and methods are described, which can be applied to both new and existing vessels.

2.1 Engineering Tools - Simulation & Modeling

The first step and basis for providing refractory solutions is the knowledge and understanding of the process mechanisms and refractory interactions. Simulation and modeling software is valuable tool for getting a theoretical insight and first estimation of the expected refractory performance taking into account thermodynamic considerations (i.e., study of the chemical interactions between process phases like slag/metal/gas and refractory lining), as well as thermomechanical behavior (i.e., expansion during heat-up and resulting stresses in the lining and furnace steel shell, tap hole simulations with thermal profile).

The thermodynamic software FactSage is a well-proven tool for studying metallurgical processes and slag systems [3]. The use of thermodynamic calculations in refractory design is a new application which has been applied and continuously improved at RHI over the last years. The theoretic calculations of interactions between refractory materials and process phases (i.e., metal, slag, gas) serve as a first basis for refractory selection and allow comparing different refractory materials for the individual process, hence reducing the required experimental work. However, expert process and refractory knowledge is vital to interpret the results and give corresponding refractory suggestions.

RHI generally provides refractory design in 2D and 3D, the latter allowing a better insight into furnace areas with complex lining solutions. The lining engineering has to be carried out considering furnace properties and design, as well as additional factors like easy installation and repair (i.e., short furnace downtimes). Furthermore, the expansion of the selected refractory materials and combinations has to be determined and included in the lining engineering. In order to guarantee a smooth practical refractory implementation and furnace operations, heat-up instructions and cool-down guidelines both for planned shutdowns and emergencies situations are provided, as well as repair instructions/suggestions and advice.

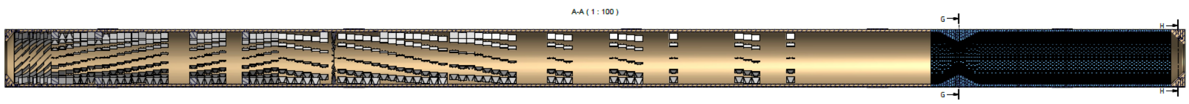

Figure 3: RHI 3D engineering - rotary kiln with combined lining (monolithics and bricks)

Due to the high process temperatures and the combination of different refractory materials with different thermal behaviour, CFD (computational fluid dynamics) and FEA (finite element analysis) simulations are essential tools for analyzing complete vessels or areas of special interest (e.g., tap hole area) and study thermal expansions and heat flows, as well as resulting mechanical stresses [4,5]. These studies are vital for determining the behaviour of the lining and steel structure in order to avoid deformation and damage of the furnace.

2.2 Lining Concepts

The results from the theoretical engineering tools together with longstanding practical industry experience allow RHI to develop holistic lining concepts aiming at ensuring furnace integrity. Different requirements have to be fulfilled in distinctive vessel areas, depending on process conditions (e.g., temperature, chemical analysis of involved phases, flow conditions, state of phases - gas/liquid/solid) and furnace operations. As there are no "totally identical" smelting operations, but always some differences are present in the various smelting routes, every furnace lining concept is a tailor-made solution for the respective vessel. An additional challenge consists in changes in process parameters (e.g., ore compositions, slag fluxing, burner modifications) or reduction of lining thickness for increasing vessel capacity that require corresponding adaption of the lining concepts in existing furnaces for maintaining the furnace lifetime and performance. The main points of lining concept design are suitable material selection and harmonic combination of materials and geometries (e.g., use of specially shaped bricks, anchor systems). Depending on the process requirements, also functional products like purging plugs or slide gates are considered in the lining concept.

2.3 Products

RHI is constantly working on improving its products and product range taking advantage of its own research and development specialists (RHI Technology Center) and close collaboration with customers. As an example for recently successfully introduced products, an overview of the new material family of Sol-bonded refractory castables is given.

The new product lines COMPAC SOL and CARSIT SOL, the latter containing SiC, represent a new type of alumina-based refractory castables based on a completely different bonding system in comparison to low cement castables (LCCs) and conventional castables (CCs), namely on nano-sized silica particles. This bonding system replaces the conventional binder, namely cement, and its complex system of (hydrated) calcium-aluminate-phases that require special attention and measures during material application and heat-up [6]. The COMPAC SOL and CARSIT materials are considered as “cement-free” and combine high performance and superior physical properties of corresponding LCCs with the easy workability of CCs with additionally facilitated heat-up requirements [8,7,9,10].

Conventional alumina-based castables are cement-bonded and use water as binder forming various calcia-alumina-hydrate phases, which determine the setting and hardening of the concrete. However, the chemically bonded water and variety of hydrate phases results in dehydration over a broad temperature range and hence requires slow and careful heat-up procedures in order to avoid lining damage due to water vapour explosions. RHI’s COMPAC SOL and CARSIT SOL materials use a totally different binding system (sol-gel), where the setting and hardening of the concrete (jellying) is based on the formation of Si-O-Si bonds. This means that no chemically bonded water is present and consequently no hydrate phases are available. The sol-gel bonding allows an easy and fast drying and heat-up without having to consider dehydration.

RHI’s SOL material family offers the following advantages:

- No chemically bonded water: easy drying, no specific pre-drying requirement, fast and easy heating-up procedure
- Finer pores and pore distribution: higher refractoriness compared to LCC, less infiltration, higher chemical resistance
- Reduced ambient temperature impact on final product properties
- Reduced sensitivity to incorrect dosing of the mixing fluid
- Easily adjusted to the desired setting time
- Improved chemical resistance (e.g., alkali, sulphur, slags) compared to equivalent cement-bonded products
- Longer shelf life than low cement castables (LCC)
- Excellent mechanical properties (Figure 4), e.g. thermo-shock resistance, internal flexibility, reduced crack formation, abrasion resistance

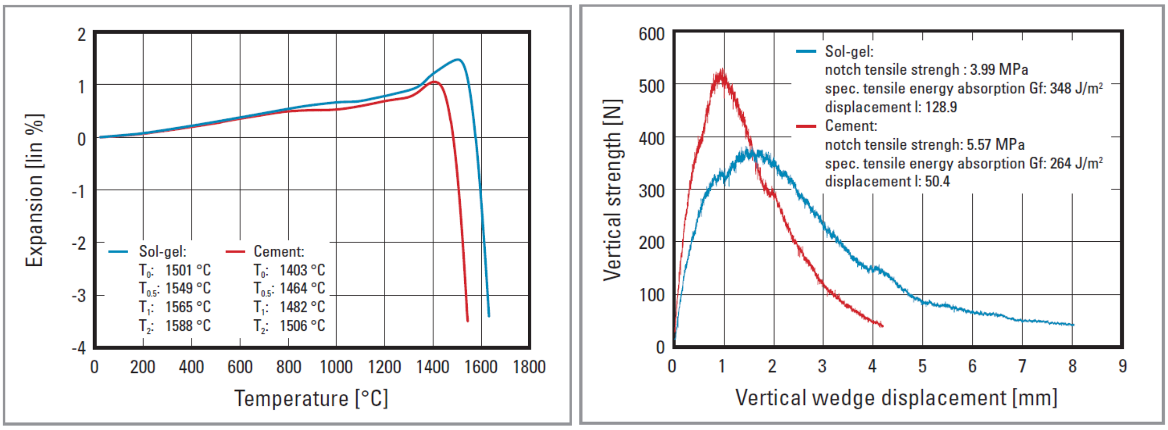

Figure 4: Comparison of refractoriness under load (left) and crack progress (wedge-splitting test) (right) for sol-bonded materials (blue lines) and cement-bonded materials (red lines)

Apart from the chemical and mechanical properties, the most interesting feature of the SOL materials is their heat-up behavior (Figure 5). The absence of chemically bounded water allows a very fast heat-up and therefore significantly reduces the furnace repair time and downtime. This is especially beneficial in furnaces that are completely or to a large extent lined with monolithic materials, for example rotary kilns in FeNi industry.

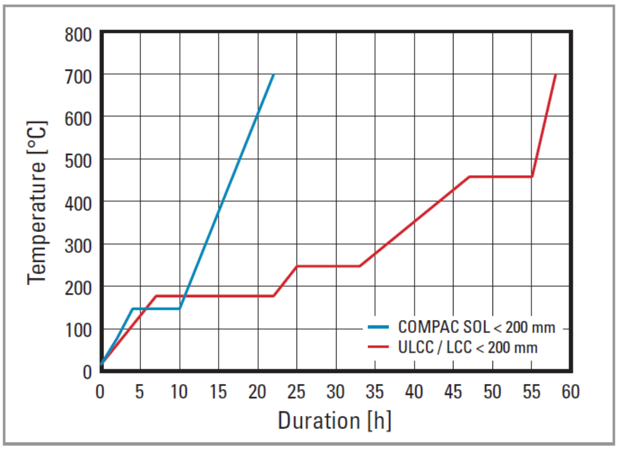

Figure 5: Comparison of heat-up procedure for COMPAC SOL and ULLC/LCC (ultra low-cement castables / low-cement castables)

The application of SOL materials does not require special installation equipment, but the existing standard casting or gunning equipment can be used. Ambient temperature does not have a significant influence on the workability of these materials and the setting behaviour is the same as for the cement-containing (i.e., hydraulic-bond) counterparts. The SOL materials can also be used for casting pre-shapes (e.g., for EAF roofs and electrode deltas). Due to their excellent physical properties and fast heat-up schedules, the SOL materials are a solution the ferroalloys industry in interested in and have already been implemented in different vessels using both castables and gunning materials. The main advantages and basis for choosing SOL materials were the absence of water and corresponding faster heat-up schedule, as well as their excellent physical properties (including abrasion) and chemical properties [8].

Some examples (and main advantages) for application of SOL materials in ferroalloy production vessels are:

- Rotary kilns: abrasion resistance, faster heat-up (especially if the kiln is completely lined with castables)
- EAF: thermo-shock resistance, abrasion resistance, chemical resistance
- Ladles: fast heat-up (i.e., heat-up schedule like for bricked ladles)
- Launders: thermo-shock resistance, fast heat-up
- SOL gunning mixes for repair and complex furnace areas

Due to their broad range of raw material bases, suitable SOL materials for various furnace areas and specific requirements are available. The practical applications have proven the laboratory research carried out at RHI's Research Center, and showed that also in industrial furnaces no pre-drying is required and the heat-up procedure is fast and safe (e.g., heat-up curves for brick linings can be used without spalling and other lining damages). Also the workability on-site proved to be convincingly easy and good enough.

2.4 Installation

In the refractory engineering stages already, considerations regarding fast and safe practical installation are included. For the actual refractory installation and heat-up, RHI provides corresponding manuals, but also its experienced supervisors and own installation personnel. Based on practical experience, installation techniques are continuously improved, for example anchoring systems, special brick retaining [5,11] and castable application technologies. The latter, together with RHI's SOL castables, results in significant reduction in furnace downtime due to time savings in both installation and heat-up.

2.5 Technical Services

For providing high-quality refractories that fulfil and exceed customer expectations, knowledge of refractory materials and metallurgical processes are required. Development of new materials as well as experimental testing is carried out at RHI's Technology Center taking advantage of a wide variety of pilot-scale furnaces and investigation technologies. Another important technical service is the so-called post mortem studies, namely the investigation of used bricks from industrial furnaces where the refractories are exposed to a complex and mutual wear caused by chemical, thermal and mechanical stresses. These studies serve for understanding of the refractory wear mechanisms and for further product improvement and/or corresponding lining suggestions. After the bricks arrive at RHI's Technology Center, first a macroscopical analysis is carried out, defining areas for closer chemical and mineralogical investigation. The macroscopical overview already provides the first information about wear mechanism and brick condition. The closer mineralogical investigations over the brick thickness provide information about the corrosion mechanism and chemical reactions.

3 SUMMARY AND CONCLUSION

RHI's refractory solutions for the ferroalloys industry include various engineering aspects, providing customer-tailored refractory selections and concepts for furnace integrity based on process knowledge and theoretical studies as well as practical experience. The present paper gives an overview of recent developments and technologies that have already proved their advantages in practice. As the adequate choice of refractory is always essential for a successful furnace operation, a close collaboration between refractory producers and metal producers is required to ensure suitable refractory selection. For optimum practical results, not only high-quality refractory products are required, but also technical services and customer support throughout all engineering stages, installation and after-sales. Practical experience and new insights from technical discussions with metal producers facilitate lining adaption in case of process changes, as well as successful development of new products that provide further advantages in practical application and guarantee efficient, economic and safe furnace operations.

4 REFERENCES

[1] Stainless Steel in Figures 2014. International Stainless Steel Forum (ISSF), available online: www.worldstainless.org/Files/ISSF/non-image-files/PDF/ISSF_Stainless_Steel_in_Figures_2014.pdf
[2] Crundwell F.k. et al.: Extractive Metallurgy of Nickel, Cobalt and Platinum-Group Metals. pp. 49-53, Elsevier, ISBN 978-0-08-096809-4, 2011
[3] C.W. Bale, et al.: FactSage Thermochemical Software and Databases. Calphad, Vol. 26, No. 2, pp. 189-228, 2002
[4] Marshall H.U.: Finite Element Simulation of Refractories – The Challenge. RHI Bulletin 2/2012, pp 41-44, 2012
[5] Wiry A.: RHI Thrust Lock System – Case Study. RHI Bulletin 2/2014, pp.40-41, 2014
[6] Routschka G., H. Withnow (editors): Handbook of Refractory Materials, 4th edition. pp. 133-138, 145; Vulkan Verlag GmbH, ISBN 978-8027-3162-4, 2012
[7] Von der Heyde R., et al.: COMPAC SOL – The Success Story Continues with Gunning Mixes and New Product Developments. RHI Bulletin 2/2012, pp. 12-16, 2012
[8] Von der Heyde R., R. Krischanitz and M. Blajs: New Sol-Bonded Product Members – Gunning Experiences and Shotcasting Applications. RHI Bulletin 2/2013, pp. 13-16, 2013
[9] Fritsch P., R. von der Heyde and R. Krischanitz: COMPAC SOL – Operational Experience with the easy, fast heat-up no cement castables. RHI Bulletin 2/2011, pp. 42-45, 2011
[10] Hochegger M., et al.: First Practical Results with COMPAC SOL A100S-15 – A High-End Sol-Bonded Castable Designed for EAF Deltas. RHI Bulletin 1/2013, pp. 14-19, 2013
[11] Wiry A. and H.U. Marshall: RHI Thrust Lock System for Cement Rotary Kilns. RHI Bulletin 2/2013, pp. 17-19, 2013
[12] RHI Research Data