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# Flexosphere Technology—Improved Flexibility and Corrosion Resistance of Fired Magnesia-Chromite Bricks

**Flexospheres are a recent product development successfully implemented in fired magnesia-chromite bricks at RHI Magnesita. This technology focuses on inhibiting the corrosion mechanism and increasing flexibility of the refractory product. During development, the experimental investigations included chemical and physical analyses as well as standardised corrosion testing at RHI Magnesita's Technology Center Leoben (Austria). The results showed that the Flexosphere technology not only improves corrosion resistance, but also contributes to the formation of a more flexible structure, which results in better thermal shock resistance. Furthermore, a RH degasser field trial validated the laboratory results, revealing a clear performance increase compared to the standard product. Thus, the outstanding properties achieved with the patented Flexospheres make this development suitable for applications under aggressive conditions, such as the tuyere area in copper furnaces or the RH degasser in the steel industry, by guaranteeing a significant quality improvement of the magnesia-chromite product.**

## Fundamentals of Magnesia-Chromite Bricks

Magnesia-chromite bricks ($MgO-Cr_2O_3$) are employed when resistance to hot erosion and thermal shock is necessary. Moreover, chromite acts as an excellent corrosion barrier against slags of different basicity and has a maximum hot modulus of rupture between 1000–1400 °C. Chromite has the generic formula $(Mg,Fe)(Cr,Al,Fe)_2O_4$ and belongs to the spinel group.

Chromite-containing basic bricks find their application in the iron and steel industry (mostly in RH degassers, AOD converters, and safety lining applications), as well as in the nonferrous metallurgy industry, cement rotary kilns, lime shaft kilns, furnaces for refractory production, and glass furnace regeneration chambers [1].

Thermomechanical degradation and corrosion are the main phenomena involved in refractory wear and directly influence the lining lifetime. Therefore, improving refractory corrosion resistance is of vital importance for the ferrous, nonferrous, cement, and glass industries. The main wear mechanism of magnesia-chromite bricks is crack formation due to thermal shock, followed by infiltration into the refractory structure, which subsequently leads to dissolution and corrosion of the refractory product as well as further crack formation [2].

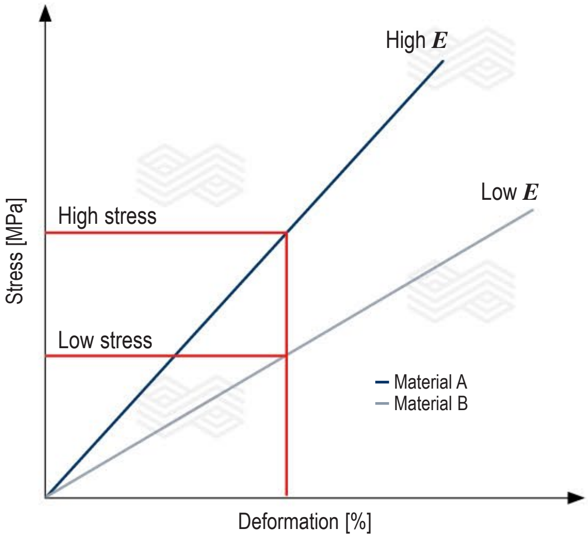
## Optimisation of Magnesia-Chromite Bricks

The Flexosphere technology is based on the Spinosphere technology, which was first introduced by RHI Magnesita in magnesia spinel grades to maintain the flexibility of cement rotary kiln bricks without compromising the hot properties [3]. The principle of this innovation was later transferred to magnesia-chromite bricks and primarily targets enhancement of flexibility and corrosion resistance.

It is well known that MgO has a high thermal expansion and is characterised as a rather brittle material when compared to other refractory oxides. As MgO is one of the two main oxides in magnesia-chromite products, the Flexosphere technology was developed to improve absorption of thermal shock in aggressive environments. There are several methods to evaluate the thermal shock resistance of refractory materials, such as measurement of the dynamic Young's modulus, the wedge splitting test, and the V-modulus. Figure 1 illustrates the Young's modulus ($E$) for two different materials. Material A demonstrates higher stress than B under the same deformation conditions, which indicates material A has a higher Young's modulus than B.

**Figure 1.**

**Representation of the Young's modulus ($E$) for different materials [4].**



The dynamic Young's modulus is proportional to the compressive stress ($\sigma$) divided by a given axial strain or deformation ($\varepsilon$). Moreover, it can be measured with the ultrasonic method and further calculated as the density ($\rho$) multiplied by the square of the ultrasonic speed ($v^2$), according to the equation below [4]:

$$E = \frac{Stress}{Deformation} = \frac{\sigma}{\varepsilon} = \rho \cdot v^2 \ \left[GPa\right] \tag{1}$$

Lower Young's moduli are characteristic of materials with a better thermal shock behaviour and give an indication of a material's flexibility.

The second competitive advantage of Flexospheres is the deceleration of slag penetration and subsequent corrosion of refractory magnesia-chromite bricks. There are several methods to assess the corrosion mechanisms of refractory samples, such as the crucible test, the rotary finger test, and the rotary slag test [2]. In the present study, dynamic corrosion wear experiments were conducted in a high frequency induction furnace (HF-IF) using the rotary finger test.

## Experimental Procedure

The initial investigations performed at RHI Magnesita's Technology Center Leoben (Austria) included preparing and mixing the raw materials, followed by shaping and pressing bricks (Figure 2). The bricks were subsequently fired in one of RHI Magnesita's tunnel kilns to ensure strong ceramic bonding of the raw materials before various chemical and physical properties, including the flexibility and corrosion resistance, were evaluated.

## Higher Flexibility and Corrosion Resistance of Magnesia-Chromite Bricks

Based on different investigations, the final refractory product was designed to increase flexibility to a maximum, while at the same time guaranteeing optimum mechanical properties. Figure 3 illustrates the dynamic Young's modulus of three specimens containing different amounts of Flexosphere (V1, V2, and V3) compared to the standard magnesia-chromite product, during a heat up and cool down cycle. The results show that the samples with the Flexosphere technology have a lower dynamic Young's modulus than the standard product and, consequently, a higher flexibility to counteract thermal shock.

**Figure 3.**

**Dynamic Young's modulus of three specimens containing different amounts of Flexosphere compared to the standard magnesia-chromite product, during a heat up and cool down cycle.**

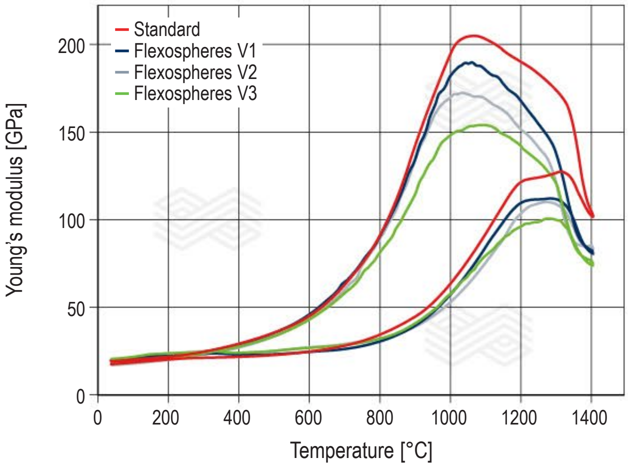
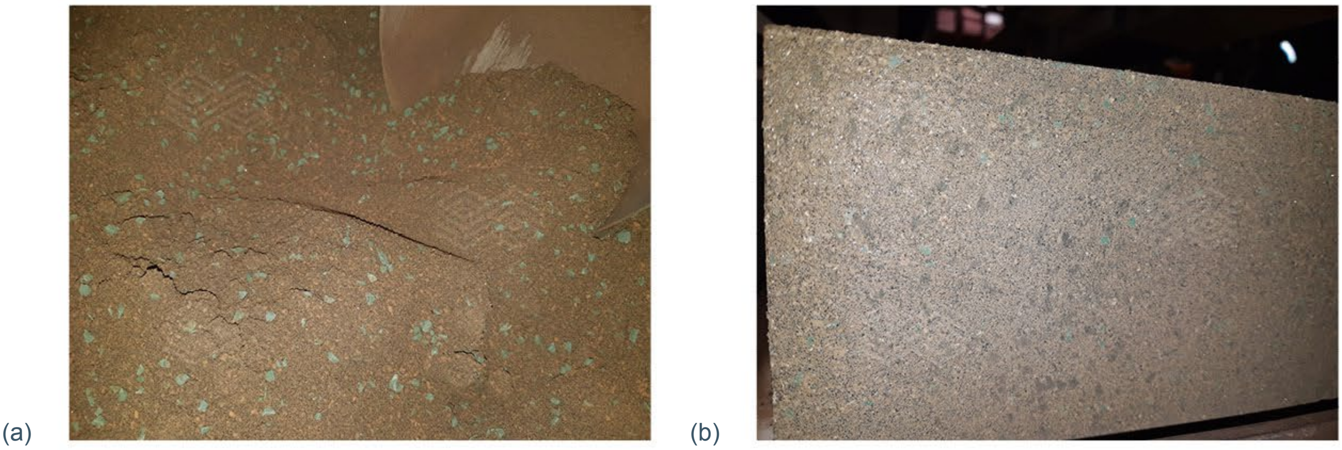


**Figure 2.**

**Magnesia-chromite raw materials after (a) mixing and (b) brick pressing.**



Another parameter to evaluate the flexibility of a product is the V-modulus, where a higher V-modulus indicates a more brittle material that is less stable against thermal shock. The Flexosphere-containing product showed lower V-modulus values indicating a higher capacity to absorb thermal fluctuations in comparison with the standard grade (Table I).

To compare the corrosion resistance of specimens with the Flexosphere technology to standard magnesia-chromite material, rotary finger tests were conducted in a HF-IF. Figure 4 illustrates the experimental setup, where typically one to four refractory fingers are submerged and rotated in the corrosive medium (i.e., metal or slag), which is contained in a crucible surrounded by heating elements [5].

Figure 5 shows macroscopic images of the fingers after a corrosion test to compare the Flexosphere technology with the standard product. Based on the maximum flux line depth, these results confirmed that the Flexosphere-containing refractory had a better performance than the standard sample due to minor slag infiltration into the refractory matrix and therefore a thicker unaltered refractory profile. The maximum flux line depth ($d_i$) is calculated as follows:

$$d_i = \frac{t_i - t_c}{2} \tag{2}$$

Where $t_i$ is the original finger thickness and $t_c$ is the finger thickness after the corrosion test.

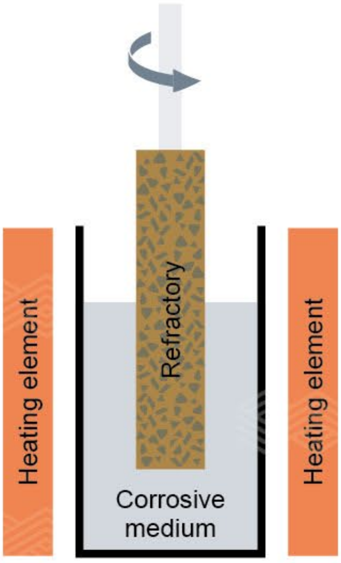
**Table I.**

**V-modulus of Flexosphere and standard magnesia-chromite products.**

| | V-modulus [N/mm$^2$] |
|---|---|
| Standard product | 8190 |
| Flexosphere product | 3437 |

**Figure 4.**

**Schematic view of a rotary finger test to evaluate the refractory corrosion mechanism.**



Light microscopy was performed on the corrosion test samples and Figure 6 shows a discontinuous slag precipitation zone on the Flexosphere-containing sample surface (A), the penetration zone (B), and the matrix (C).

**Figure 5.**

**(a) Flexosphere-containing and (b) standard magnesia-chromite fingers after the corrosion resistance test, highlighting the maximum flux line depth ($d_i$).**

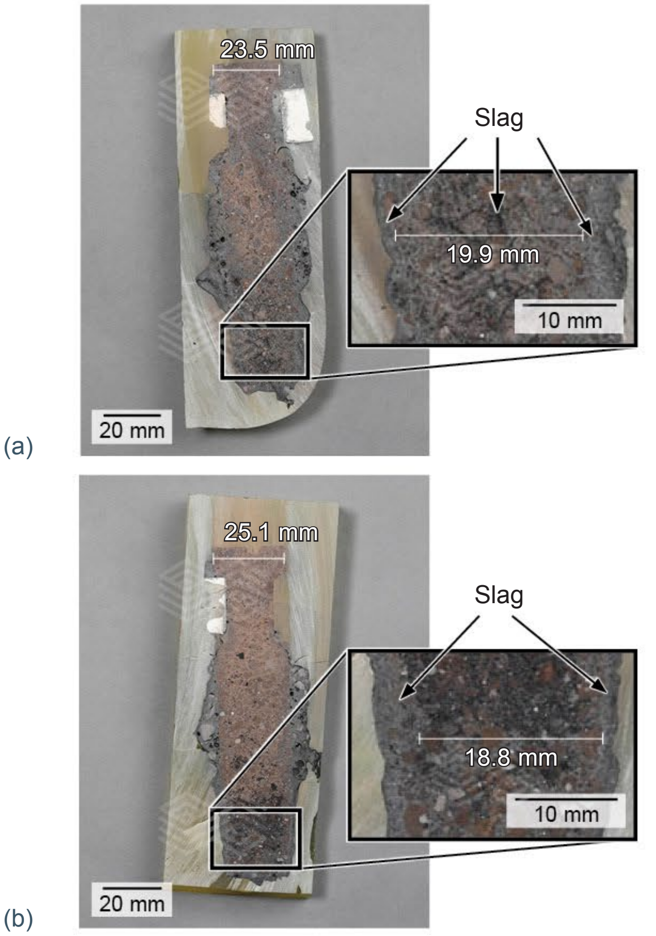
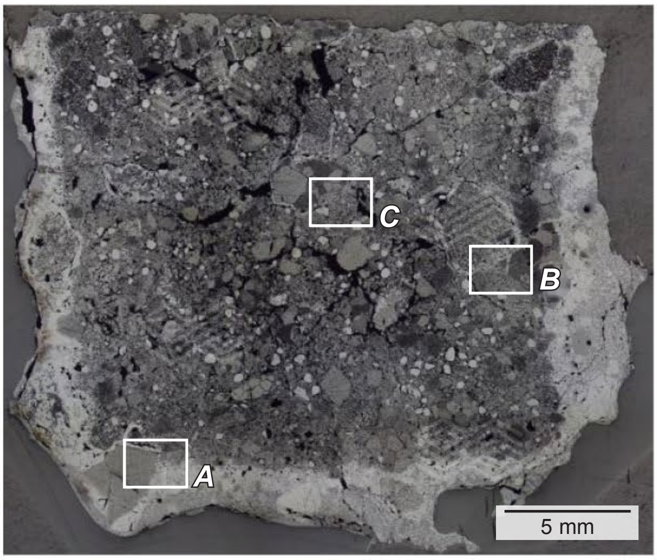


**Figure 6.**

**Light micrograph of the Flexosphere-containing material after the corrosion resistance test showing a discontinuous slag precipitation zone on the sample surface (A), the penetration zone (B), and the matrix (C).**



## Field Trial—Successful Flexosphere Application in the Steel Industry

A field trial in the lower vessel of a RH degasser confirmed and extended the results observed in the laboratory scale investigations. Magnesia-chromite bricks with the Flexosphere technology were installed as a panel in the lower vessel wear lining directly above one of the legs and the standard magnesia-chromite bricks were used to line an equivalent area above the other leg (Figure 7). Figure 8 shows a schematic section of the RH degasser, where the refractory with the Flexospheres technology is represented in blue and the standard product is marked in yellow. As the lining above the up leg usually experiences higher stresses than that above the down leg, the steel direction was switched after each leg/snorkel campaign to guarantee a uniform distribution of the wear rate. Typically, one lower vessel wear lining campaign comprises two leg/snorkel campaigns at this customer.

During the trial, relative measurements of the lower vessel lining were performed after the first leg/snorkel run and indicated a 11% performance increase of the Flexosphere-containing bricks compared to the standard magnesia-chromite material. At the end of the lower vessel campaign, absolute brick measurements could be made as the lining was dismantled and revealed a 14% performance improvement with the new development. Overall, when variables such as measurement tolerances and swapping the up and down legs were taken into consideration, it was concluded that the Flexosphere material had an improved performance of 5–15% compared to the standard magnesia-chromite bricks.

## Conclusion

The holistic approach that combined laboratory investigations as well as a field trial at one of RHI Magnesita's customers enabled the development of an innovative magnesia-chromite product. The Flexosphere technology improves the corrosion resistance and flexibility against thermal shock of magnesia-chromite bricks, resulting in a product suitable for applications under aggressive conditions such as the tuyere area in copper furnaces and the RH degasser used in the steel industry.

**Figure 8.**

**Section of the RH degasser lower vessel lining showing the magnesia-chromite Flexosphere product on the left (blue) and the standard magnesia-chromite bricks on the right (yellow).**

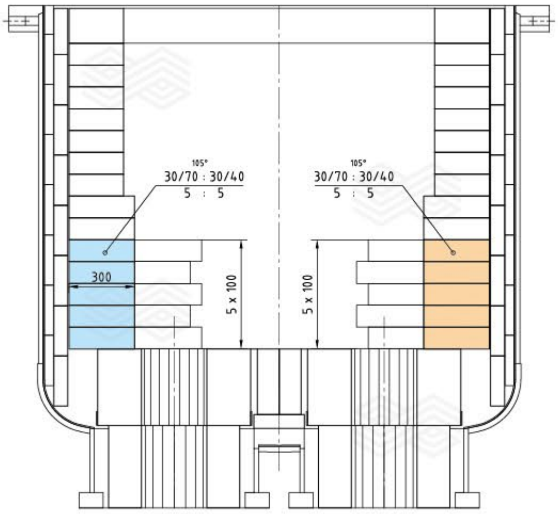


**Figure 7.**

**Standard magnesia-chromite bricks installed above the left leg and magnesia-chromite with the Flexosphere technology installed above the right leg in the RH degasser vessel.**

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**Cover picture:** The image depicts the lower section of a RH degasser, a secondary metallurgical unit used in steel plants. In the RH degassing process, snorkels are submerged into liquid steel contained in the casting ladle. Argon gas is purged through the inlet snorkel, creating a suction effect that draws liquid steel into the lower vessel of the RH degasser, where a vacuum is applied. The steel treated in the lower vessel flows back to the ladle through the outlet snorkel, creating a continuous steel circulation between the ladle and the RH degasser. The strong negative pressure (vacuum) within the RH degasser facilitates various metallurgical processes that enhance steel quality, with the key process steps including degassing, decarburisation, deoxidation, and alloying under vacuum. Rail steel, flat steel for the automotive industry, and steel plates for shipbuilding are just a few examples of products that benefit from the RH degasser. Prefabricated snorkels, which RHI MAGNESITA manufactures ready for use and delivers to our globally operating customers, are essential components of the RH degasser.