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Refractories for AF-fired kilns

The use of alternative fuels (AFs) has seen increasing demand being placed upon refractories. The Siam Refractory Industry Co Ltd has developed a third-generation refractory brick especially for the coating zone of the cement kiln where coating build-ups are unstable or coating areas shift.

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In normal operating conditions with conventional fuel use, the refractory bricks in the coating zone or central burning zone of a cement kiln need to build up a suitable amount of "stable" coating to protect the lining against several factors, including:

- high thermal load: the refractory lining in the coating zone is exposed to the highest temperature from the main burner's flame
- chemical corrosion: chemical corrosion occurs when the coated refractory bricks are directly exposed to the hostile chemical environment within the cement kiln, which includes alkalis and sulphur
- clinker infiltration: the occurrence of liquid phase whereby the chemical components within the silicate infiltrate the inner layers of the bricks and disrupts the bonding structure of the bricks
- abrasiveness from clinker balls
- reducing atmosphere
- thermal shock.

Therefore, first-generation coating zone bricks, such as hercynite-based or magnesia-chrome bricks, were developed to have the highest-possible coating adhesion strength. This enabled them to build up a thick and strong coating as fast as possible, with the highest bonding strength between the coating and the bricks. This ensured that the brick lining was protected from the adverse conditions in the coating zone.

"However, the use of alternative fuels in cement production presented brick manufacturers with an extra challenge in terms of chemical attack."

Figure 1: MultiMag performance after 704 days of continuous operation in an 4500tpd cement kiln in Thailand (photo taken in November 2019 before brick removal)

Alternative fuels as a game-changing challenge

However, the use of alternative fuels (AFs) in cement production presented brick manufacturers with an extra challenge in terms of chemical attack. As a result, a second-generation of coating zone bricks were developed: magnesia-spinel bricks. These not only build up a strong and stable coating but also have sufficient resistance to the high intensity of chemical attacks as a result of AF use.

Current cement production practices have seen an increase in AF use, both in terms of volumes and range of AFs. In addition, increased pressures on cement plants such as higher plant capacities through upgrades, increased kiln loads and heat inputs have resulted in operating conditions that exert additional pressures on the refractory lining. These factors are even more apparent in the coating zone with coating build-ups that are unstable or shift between areas and are vulnerable to the previously-mentioned challenging conditions. In addition, as coatings fall away or shift, the refractory lining of first- or second-generation bricks is pulled with it and loses its thickness.

Developing the third-generation of refractory bricks

To improve and protect the refractory lining from a range of challenging conditions and increase kiln productivity, The Siam Refractory Industry Co has introduced its third-generation MultiMag magnesia-spinel brick for coating zones with unstable coatings or shifting coating areas. The brick is well designed and manufactured from high-purity raw materials together with Siam Refractory Co's latest spinel technology.

MultiMag refractory bricks provide a range of benefits, including:

- good coatability: with thorough adjustment of the chemical composition, MultiMag is able to build

up the coating with high stability
• ability to develop a "slightly-lower" coating adhesion strength than conventional coating zone bricks, minimising the loss of brick thickness due to falls of coating and zone shifts
• good thermo-chemical reactions, thermal shock resistance and mechanical strength at elevated temperatures.

Coatability and coating adhesion strength

The coatability of MultiMag is referred to as coating adhesion strength, which can be calculated from the maximum load needed to break the bond between the brick and the coating (referred to in the test as clinker).

First, samples of MultiMag with approximate dimensions of 40 x 40 x 160mm are cut into two halves. Ordinary Portland clinker is then applied onto the cut surface to join the two parts together. The rejoined samples are loaded vertically into the gas firing furnace, where they are fired at 1400˚C (a temperature close to the condition of the coating zone in a cement kiln) for 6h before being soaked for another 30min at a temperature of 1000˚C (the condition similar to the contact area of coating and refractory lining in the kiln coating zone).

Next, a certain level load is applied to break the bonded joint of the clinker and the brick. The maximum load needed to break this joint is calculated as coating adhesion strength. This indicates how strong the coating adheres to the lining. The higher the load, the stronger the coating can adhere to the lining.

The result of the test shows that MultiMag develops slightly lower coating adhesion strength than the older generation of coating zone bricks. However, its coating adhesion strength is still higher than that of the magnesia-spinel bricks for transition zones.

In comparison with other magnesia-spinel bricks that are designed for the coating zone, the tests confirm MultiMag's characteristics.

Thermo-chemical reactions, thermal shock resistance and mechanical strength

To test MultiMag's ability to withstand thermo-chemical reactions, the brick is tested in terms of chemical corrosion with alkali salts by using the cup test method.

The test result showed that MultiMag has superior resistance against chemical abrasion, without the occurrence of cracks.

In addition, the test for chemical corrosion from clinker, carried out with chemicals in a high-temperature environment of a rotary drum, showed that in comparison with normal spinel bricks, MultiMag performed well in terms of withstanding clinker corrosion and chemical infiltration.

Furthermore, a gas permeability test assesses MultiMag in terms of gas infiltration. Test specimens are tested by how much gas can pass through them. The lower the gas permeability value, the better the brick's chemical infiltration resistance. The test indicates that MultiMag has lower gas infiltration when compared to other magnesia-spinel bricks.

In the comparative test to measure the thermal shock resistance, a specimen of MultiMag, along with specimens of other magnesia-spinel bricks, is heated to 1200˚C in the furnace for 2min and immediately cooled down by air for 5min. This cycle is continuously repeated until breakage occurs.

The result shows that MultiMag has a similar level of thermal shock resistance than that of the transition zone bricks, which is sufficient to provide MultiMag with enough resistance to thermal shock resulting from a fluctuation in the coating and shifts in coating areas.

In addition, the result of hot modulus of rupture (Hot-MOR) testing, which is the ISO-Standard Testing Approach to measure the brick strength and flexibility at a high temperature of 1400˚C, shows that MultiMag has relatively higher strength and better flexibility at high temperatures than other magnesia-spinel bricks for the coating zone, and therefore, is able to flexibly withstand a high mechanical load.

These tests prove that the MultiMag has exceptional features and is extremely well suited for coating zones with unstable coating and shifts in coating areas.

Case studies in Thailand

An outstanding performance of MultiMag was achieved in a 4500tpd Thai cement kiln (ϕ5m x 90m), where MultiMag was installed between Metres 4-12 (lower transition and coating zones) in November 2017. The brick lining lasted for 704 days with a remaining thickness of 17-18cm from an original thickness of 23cm (see Figure 1).

In a 11,000tpd cement kiln (ϕ6m x 105m) in Thailand a similar performance was reported. MultiMag bricks were installed between Metres 10-33 (coating zone) in December 2017. The brick lining lasted for 525 days with a remaining thickness of 18-19cm from an original thickness of 23cm (see Figure 2).

These tests and use in operating cement kilns have ensured that MultiMag bricks are the key to the long and satisfactory life of kiln lining in coating zones with unstable coating or shifts in coating areas. As a result, MultiMag bricks have developed into the new-generation of magnesia-spinel bricks for kiln coating zones. ■

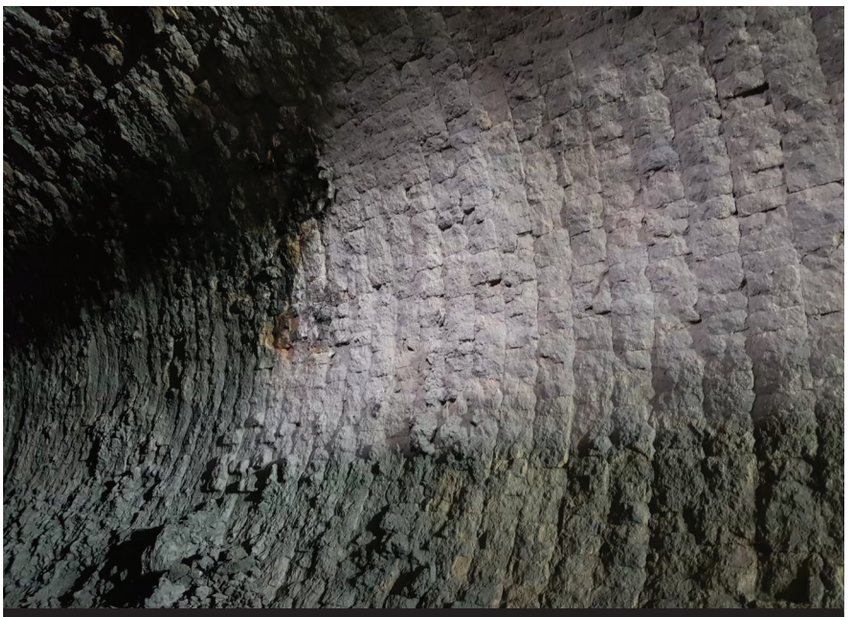

Figure 2: MultiMag performance after 525 days of continuous operation in an 11,000tpd cement kiln in Thailand (photo taken in June 2019 before brick removal)