

CORAL SMR leads the industry in effective nickel passivation

Recent benchmarking tests confirm the exceptional performance of Albemarle CORAL SMR technology, achieving the lowest dehydrogenation activity through superior nickel encapsulation. The resulting reduction in hydrogen and coke production offers significant advantages to refiners.

With the introduction of SMR technology, Albemarle continues to lead the industry in nickel encapsulation power. A comparison with state-of-the-art competitive technologies dramatically substantiates this claim. We collected a large variety of studies, mostly carried out in our customers' laboratories, which simulated FCC residue operations and comprised the latest FCC catalyst technologies, including established approaches as well as new developments with dedicated metal traps. In all of these studies, CORAL SMR outperformed the competitive benchmarks. This is illustrated in Figure 1, which compares the relative hydrogen make of these benchmarks against CORAL SMR.

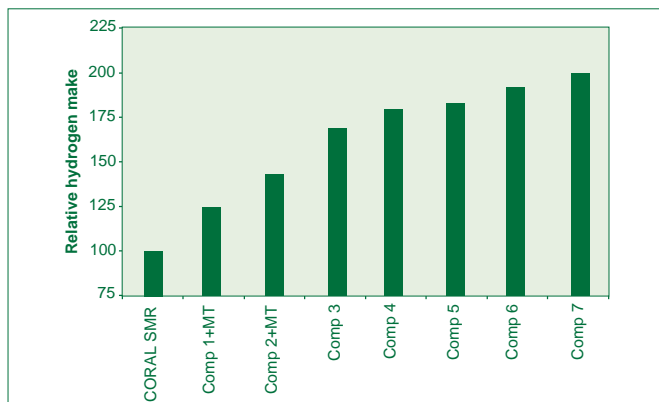


Figure 1: CORAL SMR demonstrates the lowest hydrogen make against state-of-the-art competitive benchmarks

Superior nickel passivation

CORAL SMR combines three essential features: vanadium scavenging, nickel passivation and enhanced zeolitic cracking. In this third article of a series on the remarkable CORAL SMR technology, we will focus on the mechanism for nickel passivation, which effectively achieves reduced coke and hydrogen yields in both commercial and laboratory evaluations.

Resid FCC feed contains metals in porphyrine-type structures. Nickel is deposited from these structures onto the catalyst surface, where it is well dispersed (Figure 2), creating a high surface area of active metal. This form of nickel contributes significantly to dehydrogenation reactions and promotes coke and hydrogen formation. In fact, the catalytic properties of nickel are used in several industrial applications, including hydroprocessing catalysts. But in FCC applications, the

formation of coke and hydrogen is undesirable and it is essential to reduce the activity of nickel. With the SMR technology, nickel is encapsulated in the matrix by the proper choice of materials with a high affinity for nickel. The matrix is designed to "absorb" the nickel into its structure, forming nickel aluminate which minimizes the dehydrogenation activity of nickel.

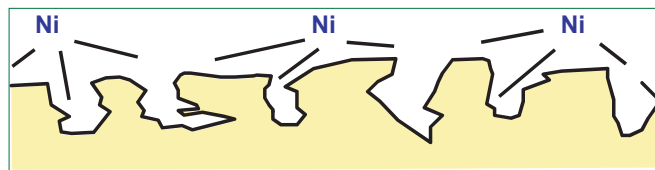


Figure 2: Impression of freshly deposited nickel on the FCC surface. nickel is well dispersed and will have a high activity in dehydrogenation reactions, resulting in high coke and hydrogen make.

SMR at the atomic level

The nickel resistant SMR matrix has an alumina spinel structure with both octaeder and tetraeder positions present. Figure 3 illustrates the alumina spinel structure prior to the reaction with nickel. A metal atom located in the center of a tetraeder (red) or an octaeder (green), is surrounded by oxygen molecules (blue balls).

Both the octaeder and tetraeder positions are occupied by aluminum atoms, as this is the predominant metal in the matrix. Some of the tetraeder positions are vacant or empty.

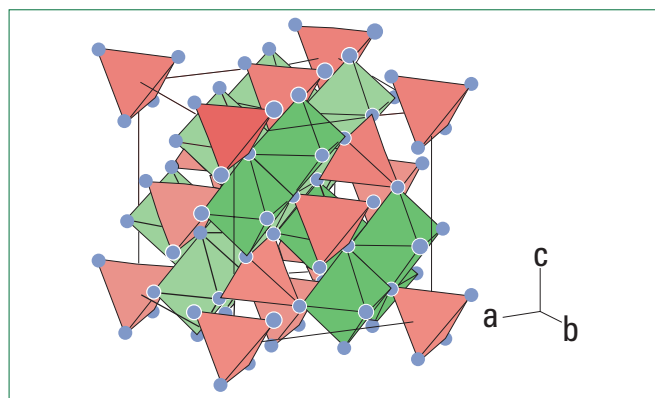


Figure 3: Schematic drawing of alumina spinel. Each blue circle represents an oxygen atom. The green octaeders and red tetraeders show the octaeder and tetraeder positions in the structure, both of which are occupied by alumina. In NiAl_2O_4 , which has the same spinel structure, most tetraeder sited are occupied by a nickel atom.

“This translates into exceptional value for refiners, through greater operational flexibility as well as increased profits.”

This aspect of the alumina structure is known in the literature and can be understood from the charge distribution. The cation:anion ratio is 2:3 in Al_2O_3 , where as it is 3:4 in regular spinel structures. To maintain the electron balance, some cation position must remain unoccupied in alumina spinel. The SMR matrix promotes the natural tendency of nickel to fill these tetraeder holes in the structure as nickel atoms on the spinel surface move to the vacant positions in the structure. Once the nickel is absorbed in the structure its activity in the dehydrogenation reaction is greatly reduced. As this process of nickel absorption continues, growing areas of nickel aluminate spinel are formed in the SMR matrix.

Microscopic confirmation

Evidence of the encapsulation mechanism can be shown by Transmission Electron Microscopy (TEM) in the analysis of commercial equilibrium catalyst samples (Figure 4) containing the nickel resistant matrix. We determined very locally the concentration of the various metals. The particular structure of the SMR matrix material allows us to determine these matrix particles on positions 3, 4 and 5. We have identified high concentrations of nickel on these spots, proving its effective capture and passivation by this material.

SMR technology dramatically reduces dehydrogenation reaction

Performance testing further illustrates the ability of SMR technology to effectively reduce dehydrogenation reactions. To compare nickel tolerance, we deactivated CORAL and CORAL SMR catalysts by Cyclic Propene Steaming at nickel levels ranging from 0 to 5000 ppm. The deactivated catalysts were then evaluated in our Short Contact Time Resid Test unit on a resid feedstock.

At increasing levels of nickel, dehydrogenation reactions are promoted, forming hydrogen and coke. The SMR

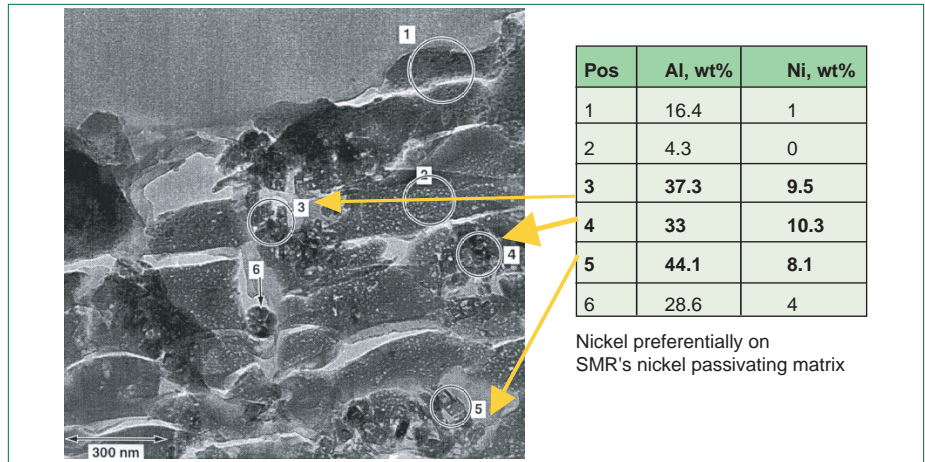


Figure 4: TEM picture of equilibrium catalysts containing nickel resistant SMR matrix. Local elemental composition has been determined in the indicated areas (Table).

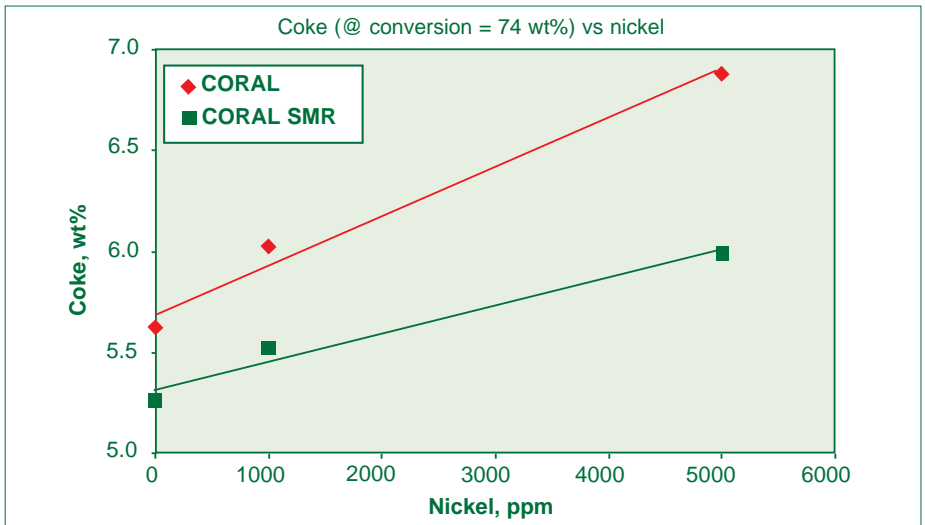


Figure 5: SMR technology suppresses dehydrogenation reactions, achieving lower coke yields.

technology reduces the dispersion of the nickel by encapsulating it into the matrix structure. The dehydrogenation reaction is strongly suppressed and lowers both hydrogen and coke yield (Figure 5). This allows a far greater operating window and enables the refiner to boost the bottom line profit.

Proven performance benefits with CORAL SMR

As we have shown, both lab analysis and commercial applications confirm that CORAL SMR leads the industry in nickel passivation, resulting in the lowest

dehydrogenation activity currently attainable. This translates into exceptional value for refiners, through greater operational flexibility as well as increased profits. Albemarle continues to evolve this exceptional technology as part of our commitment to help customers respond more effectively to an ever-changing regulatory environment.

Erratum: A revised edition of the CORAL SMR article from issue 60 is available in printed form from Albemarle and has been published to the website <http://www.albemarle.com>

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