Introducing FUSION™ Catalyst  
The Best of Both Worlds

Superior coke selectivity and bottoms cracking from a novel single particle

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One of the keys to optimal FCC catalyst performance is striking the right balance between zeolite and matrix, both in terms of selectivity and activity. Historically, catalysts systems containing (1) a high matrix input to maximize conversion of bottoms and (2) a high zeolite input to impart favorable coke and gas selectivities, has been known to outperform individual catalyst offerings. Grace has successfully commercialized these types of catalyst systems in more than 100 refineries worldwide, and they continue to form a valuable segment of our industry leading catalyst portfolio today.

Until now, however, the mechanism to unlock premium coke to bottoms performance has been achieved through the combination of two complimentary catalyst components with individual matrix technologies. Through world-class R&D, as well as manufacturing and processing advances, Grace has developed a catalyst solution, FUSION™ catalyst, which incorporates a differentiated advanced matrix binding system in a single catalyst particle. By reducing the proximate distance between multiple Grace technologies into the span of a single particle, the synergistic effects are magnified in FUSION™ catalyst to deliver premium catalyst performance for moderate and heavy metals applications.

Conversion of heavier feedstocks with high contaminant metals is critical to maximizing FCCU profitability. Increasing the yields of the desired streams such as cracked naphtha, middle distillates and light olefins remains an important target to generate an economic uplift for refiners. However, processing difficult and more cost-attractive feedstocks to produce high-value products remains a technical challenge due to limitations such as wet gas compressor and air blower capacity. With FUSION™ catalyst, Grace continues to innovate to tackle the pressures faced by the refining industry, to allow the profitable processing of ever changing and more challenging feedstocks around the globe.

A Unique Approach to Catalyst Design

The FUSION™ advanced matrix binding system deploys a combination of market-leading Grace technologies for intrinsic bottoms cracking and metals trapping into a single catalyst particle. This unique characteristic reduces the diffusion path length compared to alternative catalyst systems or separate particle metals traps solutions. Improved diffusion of heavy feed components facilitates pre-cracking of large feed molecules, and combined with the latest generation of metal trapping technologies, delivers premium coke selective bottoms cracking.

The novel single particle FUSION™ catalyst technology maintains the level of mesoporosity in the 100 to 600 Å range that is found in traditional catalyst systems but has a higher pore volume in the > 1000 Å macropore range. Macropores of > 1000 Å allow large feed molecules to effectively diffuse into the catalyst system, where the feed molecules subsequently reach the active sites and begin the series of cracking reactions. As a result, one of the key benefits of FUSION™ catalyst is additional bottoms cracking.

The FUSION™ Catalyst Advantage

- Improved FCCU product selectivity
- Increased metals tolerance (vanadium & nickel) and bottoms conversion
- Optimized porosity for increased catalytic performance
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The pore size related signatures of the FUSION™ catalyst (higher macroporosity while maintaining mesoporosity to provide the ultimate combination of bottoms cracking with coke selectivity) are demonstrated in Figure 1.

**Homogeneous Metals Tolerance**

In addition to the new pore size benefits, FUSION™ technology integrates the latest developments of commercially proven integral metals trapping technology. In many operations, the nickel content of Ecats is systematically growing, which makes it necessary to use catalysts with improved Ni trapping ability to avoid running into wet gas compressor constraints as Ni is known to produce hydrogen.

To confirm the effectiveness of Ni trapping within FUSION™ catalyst, Grace R&D performed lab catalyst deactivation by spray coating Ni on the catalyst surface, followed by CPS deactivation, to give a metal distribution that is more comparable to that of Ecats where nickel is enriched on the outer shell of the catalyst particle. X-ray powder diffraction (XRD) analysis was used as a tool to study the reactivity of γ-Al₂O₃ with nickel species to confirm the presence of the Ni passivator. The XRD pattern of the samples is shown in Figure 2. A broader reflection associated with gamma alumina is observed at 67.2° for the sample containing no nickel (Fig. 2 a). Upon increasing the Ni level of the lab-deactivated catalyst, a shift of the alumina peak to lower angular values reveals a modification of the alumina. This marks a progressive increasing of the unit cell (UC) of the alumina with increasing Ni content. A progressive enlargement of the unit cell indicates a strong interaction of nickel with γ-Al₂O₃, corresponding to the formation of sub-stochiometric Ni alumina phase.

The progressive increase of the unit cell volume of the spinel-like phase of nickel aluminate upon increasing the Ni content on the catalyst is plotted in Figure 3. The unit cell volume increases linearly with the Ni content. The linearity of the expansion of the UCV of the Ni-rich spinel-like phase upon increasing the Ni level follows a

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**Figure 1:** Hg-Pore Size Distribution of the Novel Single Particle FUSION™ vs Traditional Catalyst Systems

**Figure 2:** XRD patterns of a) FUSION™ sample with no Ni b-d) from the bottom: increasing Ni level.

**Figure 3:** Variation of the unit cell volume with increasing Ni level on lab deactivated FUSION™ sample.
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Vegard’s type law, which is described to be typical for solid solutions. This finding strongly indicates the preferential interaction of Ni\(^{2+}\) with \(\gamma\text{-Al}_2\text{O}_3\) forming solid solutions of the formula \(\text{Ni}_x\text{Al}_2\text{O}_{3+x}\). The Grace self-manufactured Ni-trap present in FUSION™ catalyst makes Ni\(^{2+}\) ions essentially non-reducible through the solid-state interaction under FCC conditions, thereby reducing the extent of dehydrogenation reactions catalyzed by Ni metal particles. This Ni trapping technology prevents enhanced coke formation as well as production of hydrogen from Ni induced dehydrogenation reactions.

To provide additional evidence to verify the hypothesis of a strong interaction of nickel with \(\gamma\text{-Al}_2\text{O}_3\), electron microprobe analysis was performed. Elemental mapping comparing the Ni with the Al map shows the preferential location of nickel on alumina particles that is clearly seen as Al/Ni hotspots in Figure 4. Considering that for these experiments the Ni was loaded in one single step (spray coating) while in commercial application the catalyst is faced with several reaction-regeneration cycles leading to a contact with a feed containing only few mg/kg of Ni (limits the formation of NiO), the XRD and electron microprobe data confirm that the Grace alumina can trap significant amounts of Ni\(^{2+}\).

FUSION™ catalyst also employs Grace’s latest generation of Integral Vanadium Trap (IVT), which is an integral rare earth based technology known from the IMPACT® and NEKTOR™ product families. While attempts using MgO- and CaO-based V traps may show promise under laboratory testing conditions, silica and sulfur within FCC regenerator conditions can poison the vanadium trap to form \(\text{Mg}_2\text{SiO}_4\) (forsterite) and \(\text{CaSO}_4\) (anhydrite). The incorporation of Grace’s integral vanadium trap enhances stability and activity retention as it protects the zeolite from vanadic acid attack, enhancing stability. Grace resid feed catalysts that contain effective integral rare earth oxide-based vanadium traps provide differentiated performance even in units with low vanadium mobility. Microprobe analysis confirms that vanadium, which is mobile under FCC regenerator conditions, migrates to regions of concentrated RE from the incorporated traps resulting in RE/V hotspots as indicated in Figure 5.

**Step-out Coke-to-bottoms Performance**

An ACE™ pilot plant was used to compare selectivities for FUSION™ catalyst against a corresponding traditional catalyst system. Both catalysts were impregnated with 3000 and 2000 mg/kg vanadium and nickel using spray coating and deactivated at the same conditions using CPS deactivation. At a given conversion, the same bottoms yield was observed for both catalyst solutions, but FUSION™ catalyst offered a significant drop in hydrogen and coke yield as demonstrated in Figure 6. The improved gas and coke selectivity provides improved coke to bottoms performance, confirming that the advanced matrix binding system causes a valuable interaction that outperforms traditional catalyst systems.
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The Pursuit of Value

At Grace, value is defined by our customer’s financial success. FUSION™ catalyst is the latest example of an innovative FCC catalyst solution designed to provide differentiated product yields and physical properties with benefits in unit retention that can withstand dynamic and challenging FCC feed profiles. The combination of the above-mentioned functional qualities and unique catalyst design architecture provides the next step improvement in value to refiners. As product economies shift in 2020 and beyond, FUSION™ catalyst provides another tool to improve our customer’s bottom line. At the time of this publication, we have new trials of FUSION™ catalyst underway in multiple regions. Please contact your local Grace representative for more information regarding FUSION™ catalyst or visit grace.com.

References