





FlexCat™ by Unifrax

Catalyst for Change: FlexCat™ Enhances Catalysis and Efficiencies

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Despite a long history of adoption, catalyst material has not changed much in nearly 40 years. Additionally, there is great interest in improving the function of catalysts in terms of yield and purity. Improving the conversion rates and yield while preserving purity and reducing side products is crucial for catalysts across all areas of use, from oil refining to petrochemical applications to emission control. As a result, many processes have failed to offer a significant, stepwise change in terms of performance.[1] In the context of this study, there is a widening demand for propene for use in the production of various polymers; thus, the discovery of a catalyst technology that allows for the efficient generation of propene from propane would be incredibly valuable to the market.[2] Fiber-based catalyst substrates meet these challenges. Testing has shown that catalyzed fiber offers a number of advantages over traditional designs by:

- **Lessening overall catalyst load:** This is significant due to the cost of platinum group metals (PGMs) typically used as catalysts.
- **Reducing weight:** By providing faster light-off and earlier reaction activity, lighter-weight materials lower the number of supports needed, the cost of industrial units, and the release of harmful emissions in emission control applications from startup.
- **Increasing fuel efficiency:** Fiber-based designs can yield devices with lower pressure drop, which leads to better fuel efficiency and less pressure on industrial pump units.

Large-scale improvements are still needed for a more cost-effective solution to revolutionize the catalyst industry to increase yields without generating harmful byproducts. But by applying some 75 years of innovative fiber manufacturing experience, **Unifrax** solves for these challenges with **FlexCat™**—a revolutionary, high surface area, fiber-based, flexible catalyst support solution that does what other products can't by maximizing surface area and catalyst contact, enhancing cost-effectiveness, increasing yield with reduced catalyst weight in the reactor, and preserving purity.

In a perfect world, the ideal fibrous catalyst support media would offer:

- High geometric surface area
- Resistance to thermal shock, wear, and attrition
- Adaptability into a viable product form that considers reactor space and infrastructure
- Arrangement and design that preserves required pressure drop
- Comparability with multiple active catalysts, promoting and stabilizing elements and agents
- A stable porous microstructure
- Availability at viable scale

Until the development of **Unifrax**'s **FlexCat**, limited research had been done on impregnating and studying catalytic conversion among other properties of fibrous supports; **FlexCat** is now in validation with industry leaders. A fixed-bed model reactor with a high geometric surface area can overcome heat- and mass-transfer limitations, with yields that approach that of equilibrium conversion; however, in such applications, the pressure drop can limit effectiveness.[3, 4]

To successfully commercialize fibrous catalyst support materials, companies need to engage in multi-disciplinary, multi-faceted projects with catalyst developers, designers, and support manufacturers to develop fully optimized units while navigating material costs in relation to other factors in these complex units.

Boosting Yield and Throughput

Historically, the catalysis industry has relied on alumina supports to execute chemical reactions. **Alumina shapes**—like pellets, spheres, and extrudates—typically are used in petrochemical and processing chemical reactions, while **cordierite monolithic** or **foil supports** are used primarily in emission control applications. But the former, especially, comes with challenges: inefficient performance, greater expense, and susceptibility to uneven thermal gradients in the reactor bed.

Yield and throughput measure how much material or feedstock has passed through a catalyst and been converted to the desired product during a given time and flow rate. Yield is also defined as a function of catalyst mass or volume—meaning a catalyst solution can generate more yield or throughput even while being installed in a smaller, less voluminous form. The benefits of increasing yield while reducing catalyst weight are numerous: the overall installation footprint can be smaller and/or additional catalyst units or beds can be installed in an existing unit, thereby increasing yield even further. Currently, the best way the industry has to increase reactor output or yield using traditional catalyst materials and formulations is to build out additional units, but these require physical space availability and additional infrastructure and can be very expensive, costing upwards of $200 million.[5] Thus, to improve yield, output, and even purity in such installations, the best solutions require a far greater surface area than what traditional supports can provide.

Spurring on Solutions

Partnerships with licensers, catalyst synthesizers, and reactor designers can greatly accelerate the catalyst development process and deployment in the field. In essence, the industry needs the right combination of application, catalyst formulation, and process conditions to realize larger increases in yield while also extending the lifetime of the catalyst in the reactor. Benefit and value are realized as faster regeneration times lead to additional hours on stream. For example, increasing the time on stream (TOS) by even a few hours allows for more yield per cycle prior to regeneration, by utilizing **FlexCat**.[2, 6]

Utilizing a catalyst support solution brings both advantages and disadvantages to the table. Typical catalyst support materials comprise varying shapes and chemistries, including alumina, cordierites, mullites, and silicon carbide, which are chosen due to their resistance to thermal shock, wear, chemical/corrosion resistance, and porosity. Increasing the surface area often means reducing the size of the support…but typically, this comes at the expense of particle or support strength and differential pressure

Fiber-Based Technology That Delivers

With **Unifrax**'s innovative, flexible mat-based catalyst support media, **FlexCat** is transforming the industry—increasing yield over traditional media with 50% fewer side products and 40% faster regeneration times in the model reaction studies in this publication. Our custom, modular product forms have up to 10 times less weight than traditional media and are stable up to 900°C alongside:

- **Controlled industrial emissions:** Existing systems will not meet stricter regulations: **FlexCat** provides the adaptability to enhance existing systems for better conversion and performance or enable new, smaller, and more effective units to meet increased standards worldwide.
- **Advanced hydrogen production:** **FlexCat** supports the growth of hydrogen production—from large-scale operations and fuel cells to consumer applications—through better selectivity and increased yield by using significantly reduced catalyst loads and space footprints.
- **Improved catalysis technology for petrochemical and refining:** **FlexCat**'s increased performance boosts yield from existing equipment by 40%, allowing operations to scale without costly capital expenditures. Enhanced selectivity and reduced coke production afford operators reduced downtime, fewer shutdowns, and safer turnovers for employees.

(or pressure drop) across the media bed due to a denser packing within the reactor. In practice, the best solution would entail using a mixture of large- to small-sized support particles to compensate for gaps in the crush strength and increases in differential pressure.

With its long tradition of manufacturing innovative solutions for various industries, **Unifrax** set about creating a new option to overcome limitations and expand benefits. With an exceptionally high surface area (up to 50 times greater), 40% faster regeneration time, and ability to increase yield while preserving purity, **FlexCat™** disrupts traditional catalysis technology across industrial markets by:

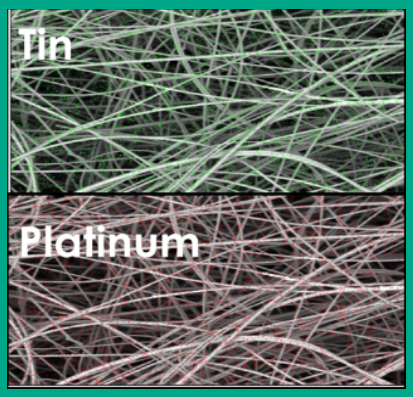
- Providing a lightweight fiber mat structure, which allows for smaller reactors and lower investment costs
- Boosting effectiveness (e.g., higher yield with smaller units, reducing catalyst load, lowering operational costs, protecting purity)
- Increasing employee safety across a number of applications
- Ensuring a greener, cleaner, and safer solution with less waste

Customizing Catalysis with FlexCat

Current goals for catalyst support innovation entail moving from static, long-established technology to novel, flexible supports that afford a significant step change in yield, purity, regeneration time, and coke laydown in existing installations or new builds. **Unifrax** brings such a fibrous catalyst support solution to the forefront with a fiber mat that can be customized for a myriad of catalysis operations. It is designed to work across several markets to provide enhanced catalyst effectiveness with increased yield for any type of catalytic reaction, including hydrogen production, industrial emission control, and traditional chemical feedstock applications.

FlexCat brings the benefits, with:

High alumina, highly amorphous fibrous support material: Designed with a high internal surface area and defined surface microstructure, **FlexCat** can accommodate and directly adhere active elements including Cu, Pt, Pd, Ni, Fe (*see Fig. 1*).



Equivalent mass of FlexCat fiber yields a 50x increase geometric surface area compared standard pellets or spheres

Property	Target
Alumina (%)	96
Silica (%)	4
Surface area (m^2/g)	120–140
Specific surface area (m^2/m^3)	40,000
Pore size (Å) (per fiber)	60–75
Pore volume (cm^3/g)	>0.15
Median fibre diameter (µm)	4

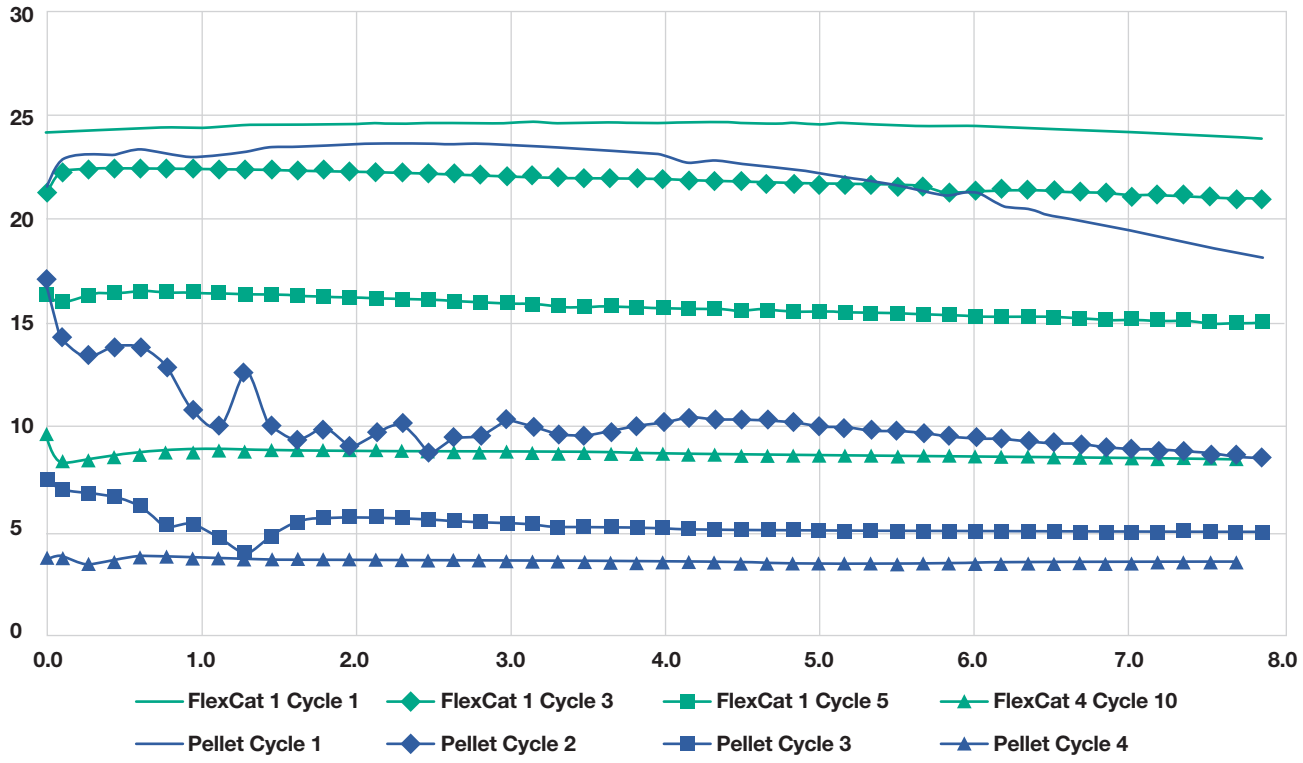
Fig. 1: ***Example of superior surface area over standard pellets***

Strong performance in propane dehydrogenation reaction, tested under rigorous conditions: **Unifrax** worked with a reputable catalyst development and evaluation laboratory and catalytic performance testing confirmed **FlexCat**'s overall increase in yield and improved run-to-run stability compared to a conventional pellet support media.

Increased hourly propene yield (g/hr.): In testing under 590°C, 2 barg, 72 ml/min for 8 to 16 hr^{-1} WHSV, **FlexCat** demonstrated:

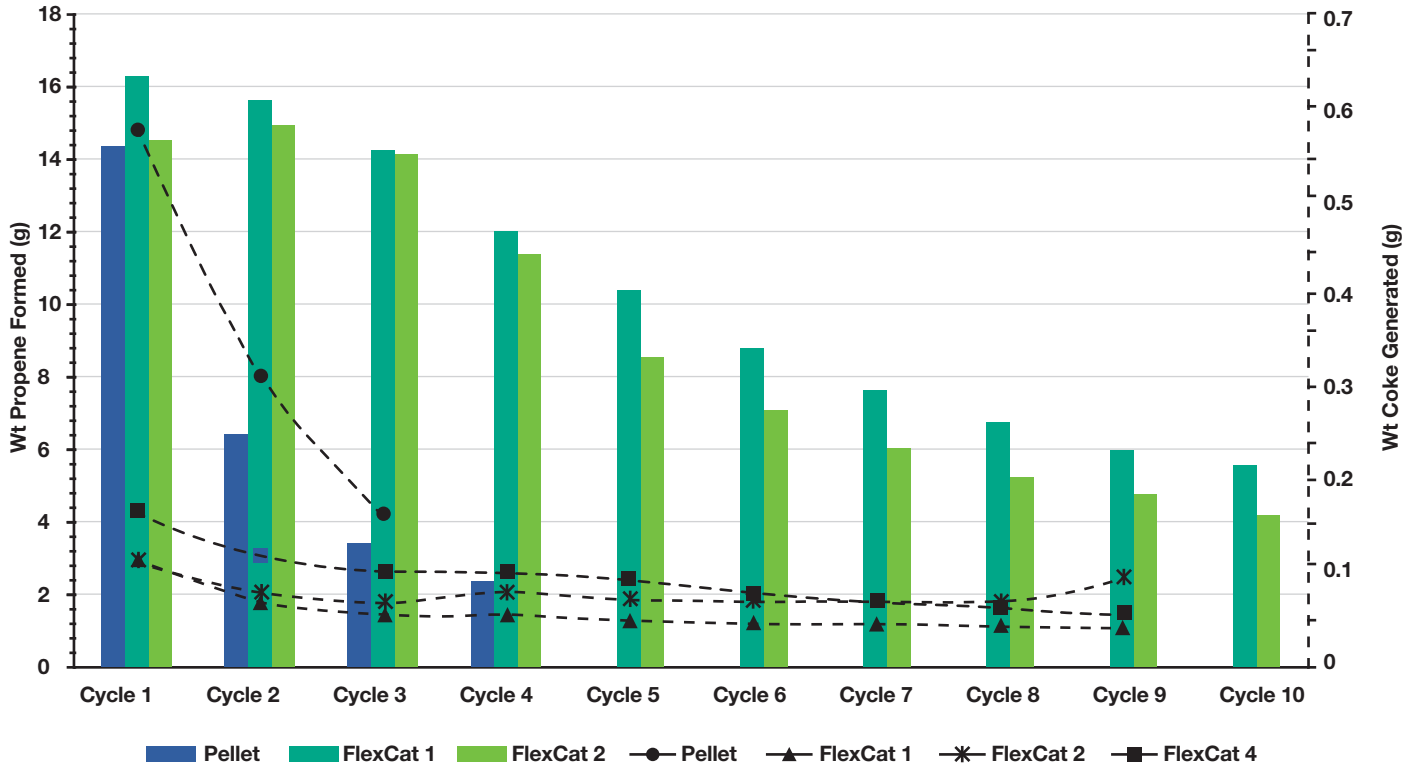
- Greater gravimetric yield of propene (g) compared to incumbent pellet support material, realizing the same yield using less catalyst mass and thus a smaller footprint (*see Fig. 2*).
- Higher geometric surface area that enables greater feedstock contact with active catalyst (Pt) for increased throughput and yield per hour (>40%) while fixing all other conditions, such as flow rate.

Fig. 2: ***Test results depicting FlexCat's vastly increased propene yield vs. pellets***

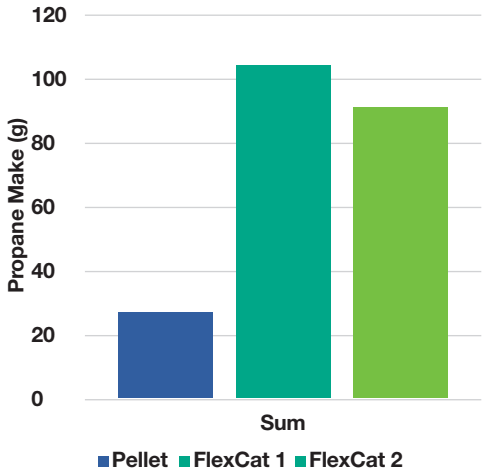


Fibrous material that allows for dramatically increased selectivity (50%): This translates into fivefold less benzene formation, which is critical to reducing side products in the outlet (for easier downstream purification) and limiting coke laydown (up to 80% reduced coke/carbon laydown after each cycle for greater long-term support efficacy). Limiting coke laydown can lengthen catalyst lifetime by preventing deactivation and blinding of the catalyst. Reducing the amount of coke laydown prior to regeneration also reduces the chances for local hotspots on the catalyst surface and subsequent permanent damage to the catalyst through sintering or reduction of pores.[2]

Fig. 3: *Test results demonstrating less coke/benzene formation*



Sample	Weight	Wt Pt	Wt Sn	Sn:Pt
Pellet	4.0	0.024	0.068	3.0
FlexCat 1	1.2	0.023	0.073	3.0
FlexCat 2	0.5	0.022	0.028	1.0



A proven faster rate of regeneration: Thanks to limited coke buildup and a high surface area, regeneration time is 40% faster than pellets without adjusting jacket/reactor temperatures, thereby allowing plants to get back to producing faster. While the regeneration process requires synthetic air, it utilizes only 5% O_2 at most to burn off excess coke, versus pellets which can require up to 20% O_2.

Less susceptible to irreversible deactivation: Under the conditions described, **FlexCat** exhibits greater run-to-run stability and a demonstrated superior resistance to irreversible deactivation.

Stability of microstructure and amorphous alumina: Post-conversion analysis using common methods like XRD and N_2 adsorption - BET surface area demonstrates that the fibrous catalyst support is not damaged after cycling but rather remains highly porous, with a well-defined surface microstructure, as surface area and pore volume remain unchanged. The temperatures required for conversion and the consecutive regenerations did not alter the phase of the alumina, γ-alumina.

Flexible use to leverage existing reactor space or customize new builds: **FlexCat** has the potential for drop-in use with existing reactor designs or new builds. Its model cylindrical form was designed to expand the geometric surface area while limiting pressure drop to 35 mbar at a flow rate of 390 CFM and face velocity of 2.6 ft/s. After over 100 hours at these conditions, stability pressure-drop testing suggested that **FlexCat**'s fiber form was durable, without excess wear, by-pass, or tunneling.

Driving Global Demand

Unifrax wisely took a manufacturing-led approach in developing **FlexCat** to meet global demand and enable massive benefits across the board. Utilizing a scalable process and readily available materials, **FlexCat** technology stemmed from **Unifrax**'s established fiber process technologies. The company's proven development expertise in inorganic materials and ability to scale manufacturing to a global level translated into creating a product with tremendous flexibility.

- Offers a defined microstructure that makes it an ideal candidate to handle multiple catalyst loads (<10% by weight)
- Can handle the stress and conditions of particular reactor environments. Third-party aging studies show no change to the fiber crystallinity and microstructure after aging at temperatures above 980°C under steam-rich conditions for 24 hours
- Improves conventional catalyst supports with its defined porous surface microstructure, which allows direct loading of the catalyst onto the fiber (i.e., without alumina carriers or washcoat)
- Offers a high specific surface area and enhanced tortuosity
- Reduces catalyst load and reactor footprints while remaining stable in aggressive atmospheres over 900°C
- Is ready for on-demand production at tonnage scale
- Is customizable to fit specific catalytic applications in several industries and can be delivered at commercial scale, based on customers' needs

While there are many factors to consider when deploying such a technology in the field, **Unifrax** focused on the technical practicalities of bringing such a fiber to product form, including impregnation, part assembly, and installation. Designed for differing uses and industries, **FlexCat** is a game-changer, offering a revolutionary catalyst support media to provide enhanced catalyst effectiveness while increasing yields, purity, and cost savings.

FlexCat Benefits

Replaces Pellet with Fiber

- 15x less mass vs. traditional forms
- 50x more specific surface area (m^2/m^3) compared to traditional catalyst media
- High alumina catalyst support, gamma and transitional alumina
- Direct catalyst impregnation—no additional carrier needed
- Stable product form at temperatures >900°C

Increases Production, Reduces Downtime

- 40% faster regeneration time in dehydrogenation compared to traditional processes
- Excellent resistance to deactivation and enhanced selectivity
- Up to 10x less total catalyst weight due to faster, easier loading of modular product forms

Boosts Throughput

- 4x more yield in propane dehydrogenation
- Begins converting carbon monoxide and volatile organic compound emissions at approximately 180°C
- Tortuous path offers greater surface area for increased interaction with catalyst
- Durable catalyst adhesion throughout life cycle

Maximizes Plant Yield, Minimizes Carbon Footprint

- 5x less coke and benzene formation
- dP controlled through custom-designed product form

Conclusion

The existing catalyst support space needs innovative solutions; rising costs suggest that improving catalysts means boosting conversion of a given feedstock while also limiting side products and coke buildup.[7] But advancements in heterogeneous catalyst support technology can also help by improving performance and yield/output. The ideal catalyst support will leverage high surface areas while being installed in such a way that minimizes pressure drop, side products, and coke formation, with the ultimate goal of achieving additional yield and feedstock conversion while offering longer lifetimes and reduced regeneration times.

Developed by manufacturing leader **Unifrax**, **FlexCat** solves for these challenges with its unique, high surface area fiber, providing a defined microstructure that defies the usual tradeoff between increased yield and coke buildup/side products that occur in high alumina catalyst support media. Third-party testing has demonstrated a 40% increase in propene yield/hour and 75% more propene yield across 10 cycles. Furthermore, data showed fewer side products and lower regeneration times in a microtube reactor system that modeled a high-value reaction, propane dehydrogenation. Finally, **FlexCat** can be loaded into a viable product form for retrofitting existing installations or construction of new installations. Based on these results, **FlexCat** is in current validation projects across the catalysis value chain—including work with catalyzers, licensors and process designers in the industry.

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Partner with FlexCat

*Customizable for individual partners, processes, and specific reactions, **FlexCat** can be manufactured at scale today. **Unifrax** is currently looking to expand their customer validation group testing **FlexCat**. To learn more on this new data or to begin a design study for a particular application, please visit www.unifrax.com/flexcat or email info@unifrax.com.*

About Unifrax

__Unifrax__ develops and manufactures high-performance specialty materials used in advanced applications, including high-temperature industrial insulation, electric vehicles, energy storage, filtration, and fire protection, among many others. __Unifrax__ products are designed with the ultimate goal of saving energy, reducing pollution, and improving safety for people, buildings, and equipment by delivering on our commitment to our customers of greener, cleaner, safer solutions for their application challenges. __Unifrax__ has 37 manufacturing facilities operating in 12 countries and employs 2,700+ employees globally. More information is available at www.unifrax.com. For updates, follow us on Twitter, LinkedIn and Facebook.