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DEEP OXIDATION OF TOLUENE ON GLASS-FIBER CATALYSTS IN THE STRUCTURED CARTRIDGES OF VARIOUS SHAPES

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Introduction

- Catalytic abatement of organic solvent vapors for the reduction of environmental pollution is an important problem in the modern world. One of the directions for its solution is application of deep oxidation reactions on glass-fiber catalysts (GFCs)
- The aim of this work is to study the dependence of apparent activity of the structured GFC cartridge upon the different GFC layers arrangement in relation to the reaction mixture flow, as well as the influence of structuring elements of different shapes and glass-fiber of various weaving types

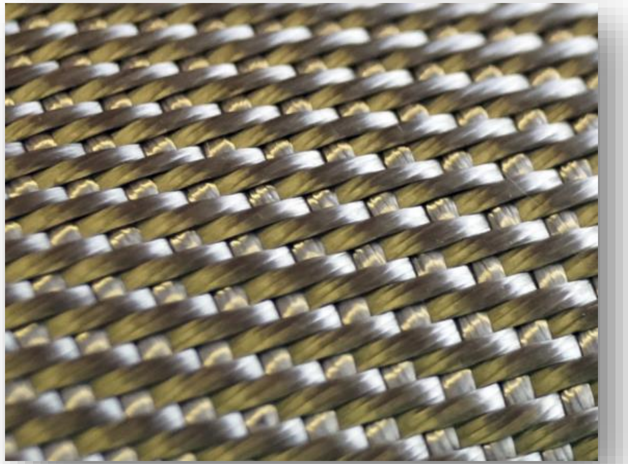
Synthesis of catalysts

- Platinum was used as an active component in all catalyst samples. Several different samples were prepared
- The precursor solution was applied to the glass fiber substrate by incipient wetness impregnation or by spray application
- Then the samples were processed by surface thermosynthesis. After preparation, the catalyst in the cartridges was structured in various ways
- Two types of glass fiber supports were used for manufacturing of catalysts: sateen and openwork
- In addition, a sample of the commercial glass- fiber catalyst IC-12-S102 was used for comparison
- GFC layers in the cartridges were located longitudinally and transversely to the flow
- A 3D mesh or flat and corrugated mesh layers were used as structuring elements between the catalyst layers
- The platinum content in the sprayed sample was ~ 0.02 wt%, in the impregnated specimens in terms of moisture capacity was ~ 0.08 wt%, IC-12-S102 ~ 0.03 wt%.

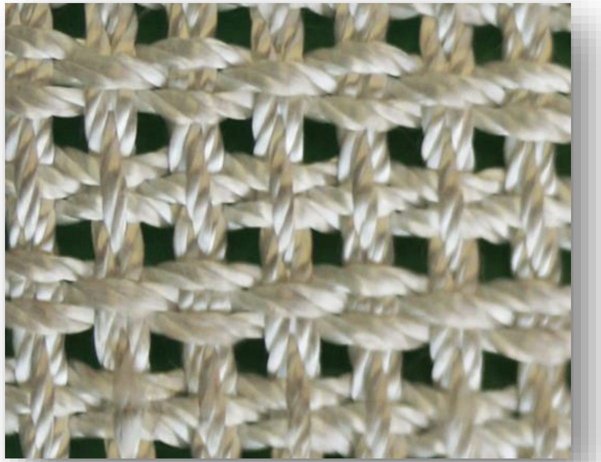
Geometry of glass fiber catalysts

- Glass fiber catalysts differ both in the type of weaving of glass microfibers (sateen, openwork)

An example of GFCs with various applied active components

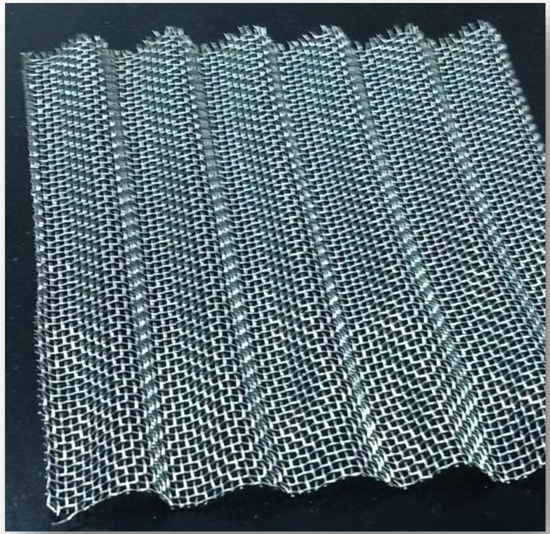


Weave type sateen

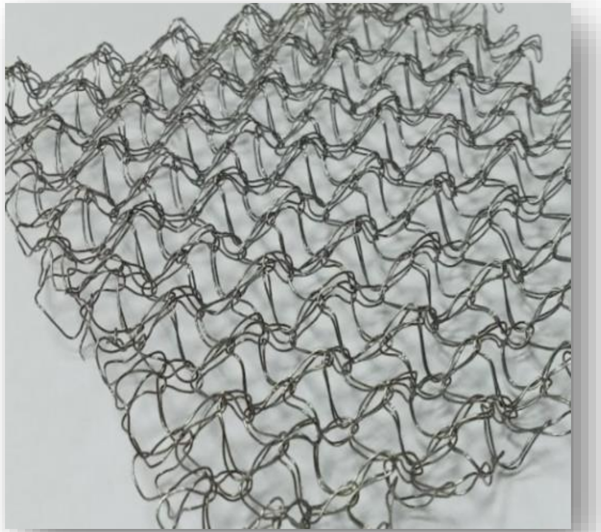


Weaving type openwork

Method of structuring of glass-fiber catalysts into a cartridge with longitudinal flow



Corrugated mesh structuring element



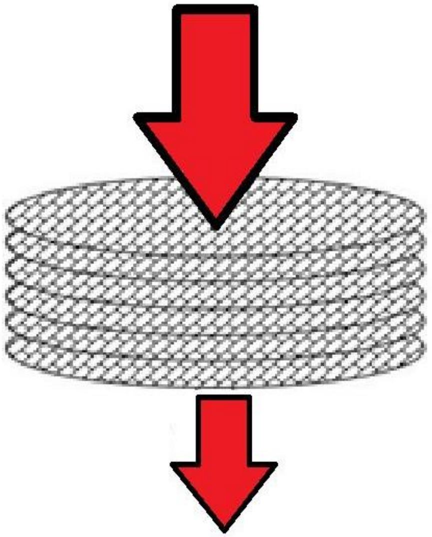
Structuring element 3D mesh

Packing with longitudinal arrangement of layers

Structuring the GFCs into cartridges can be done in different ways. With the use of elements in the form of a corrugated metal mesh or three-dimensional mesh, with a different arrangement of layers of GFCs

Multilayer packing (MLP)

- With multilayer packing with propagating flow, a greater contact of the reaction mixture with the catalyst is possible; however, with such packing, the hydraulic resistance is higher compared to the longitudinal arrangement of the layers
- The pressure drop can probably be reduced by using a 3D mesh between the GFC layers



Cross-flow bedding

Multilayer packing
with propagating flow

Experimental method

- Air passes through the toluene in the saturator then mixes with the mainstream to form a reaction mixture.

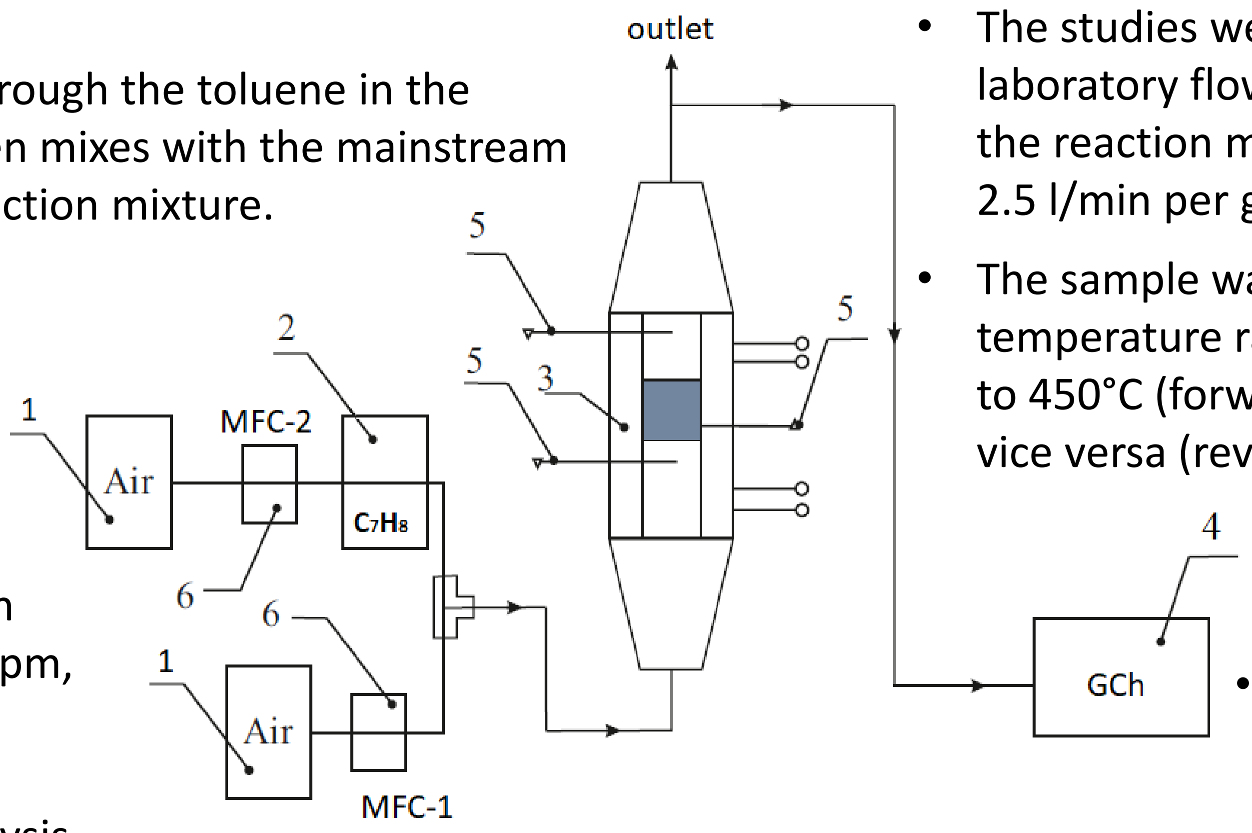


Diagram of the experimental setup: 1 - air from the system, 2 - saturator with toluene, 3 - reactor, 4 - gas chromatograph, 5 - thermocouples in the lower and upper zones of the reactor and in the catalyst cartridge, 6 - mass flow controllers MFC-1 and MFC- 2

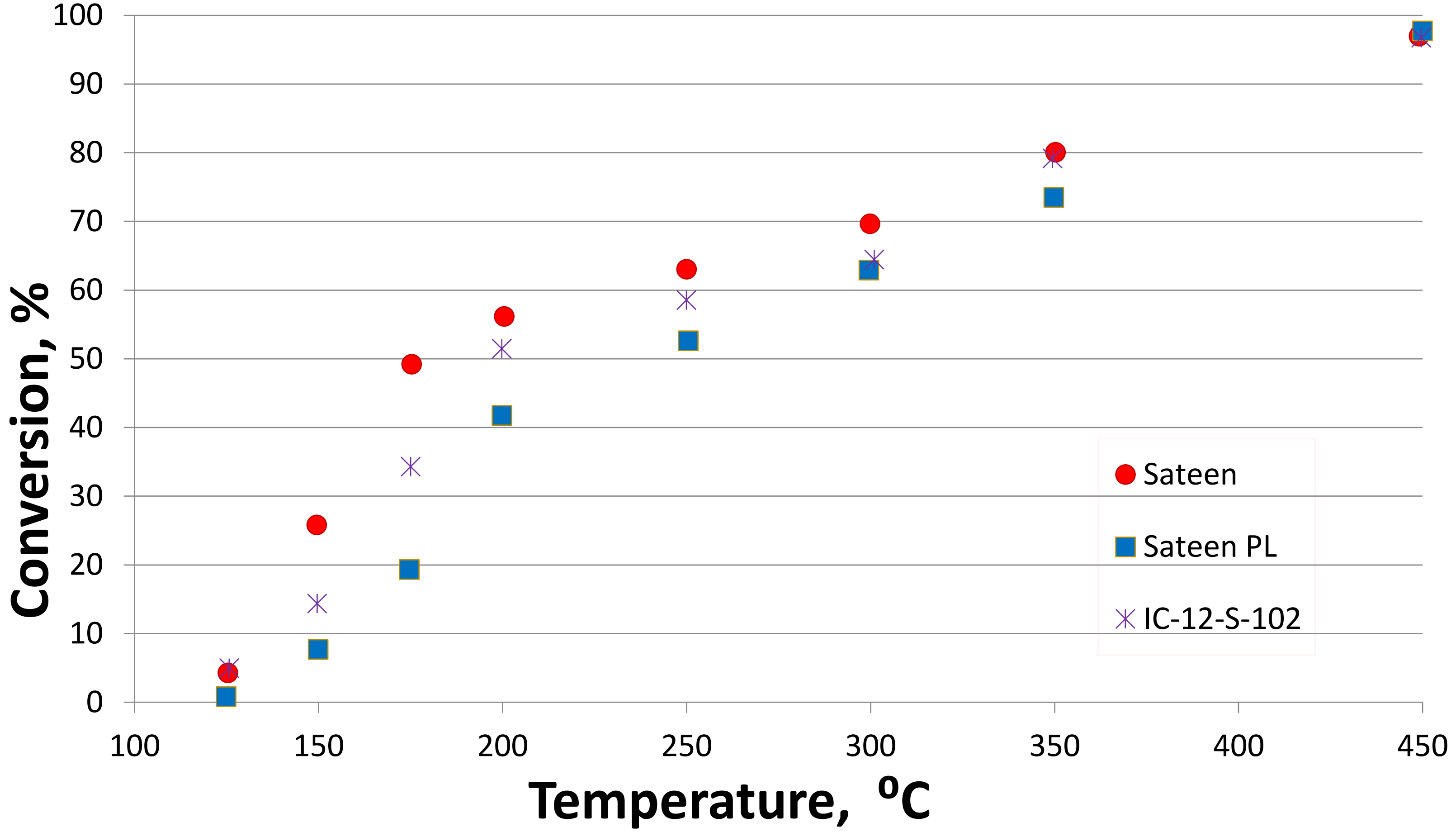
- The concentration was taken ~ 100ppm, since such a concentration is sufficient for analysis and at the same time allows avoiding disturbing influences

- The studies were carried out in a laboratory flow reactor. The flow rate of the reaction mixture of toluene and air was 2.5 l/min per gram of catalyst.
- The sample was exposed to temperature range from 100°C to 450°C (forward passage) and vice versa (reverse passage).

- The reaction mixture was analyzed at the inlet and outlet of the reactor using a Crystall-2000M gas chromatograph.

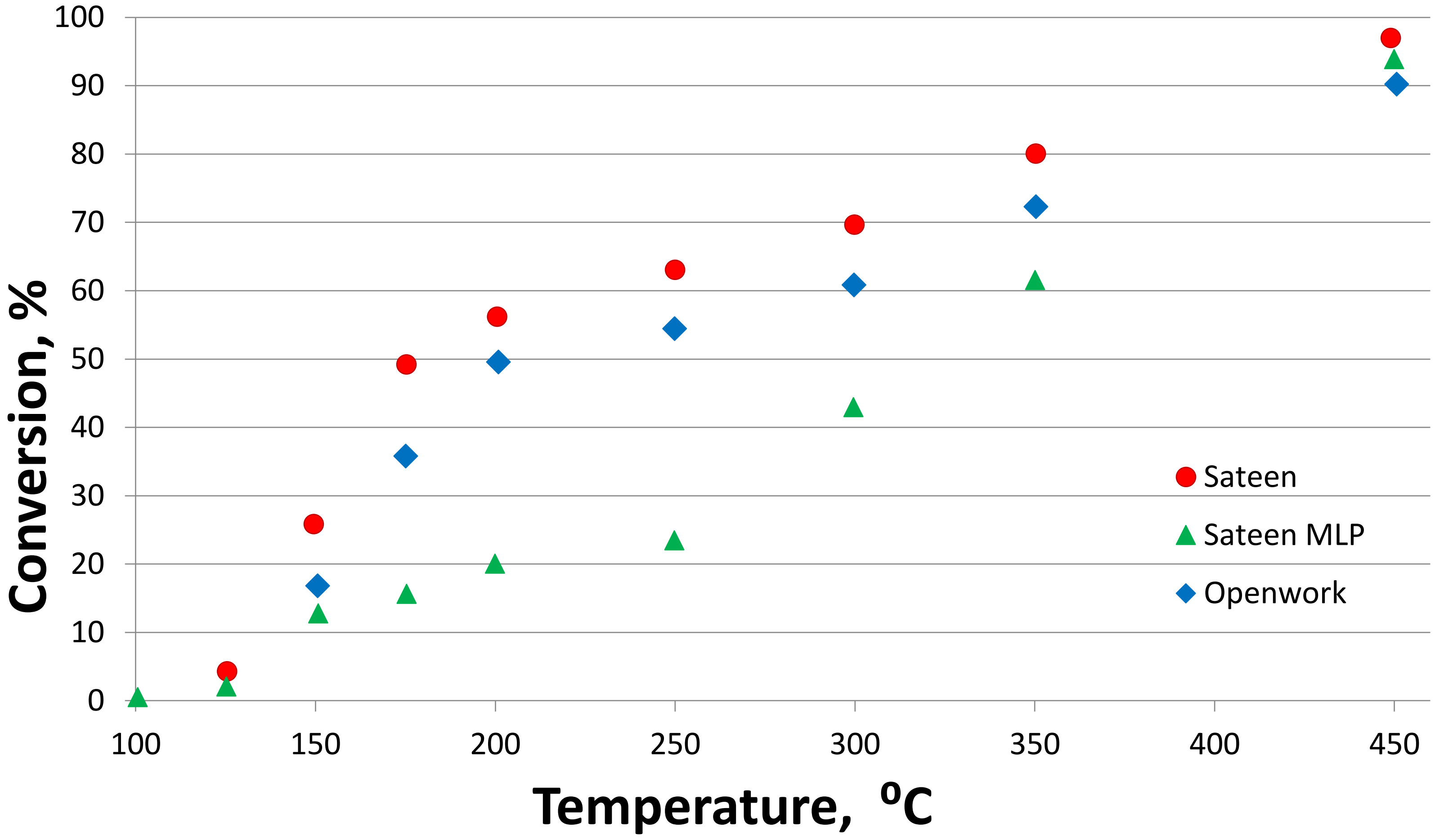
Reactor

Comparison of the apparent activity of cartridges with the same channel height (5 mm) and structured elements in the form of a corrugated mesh



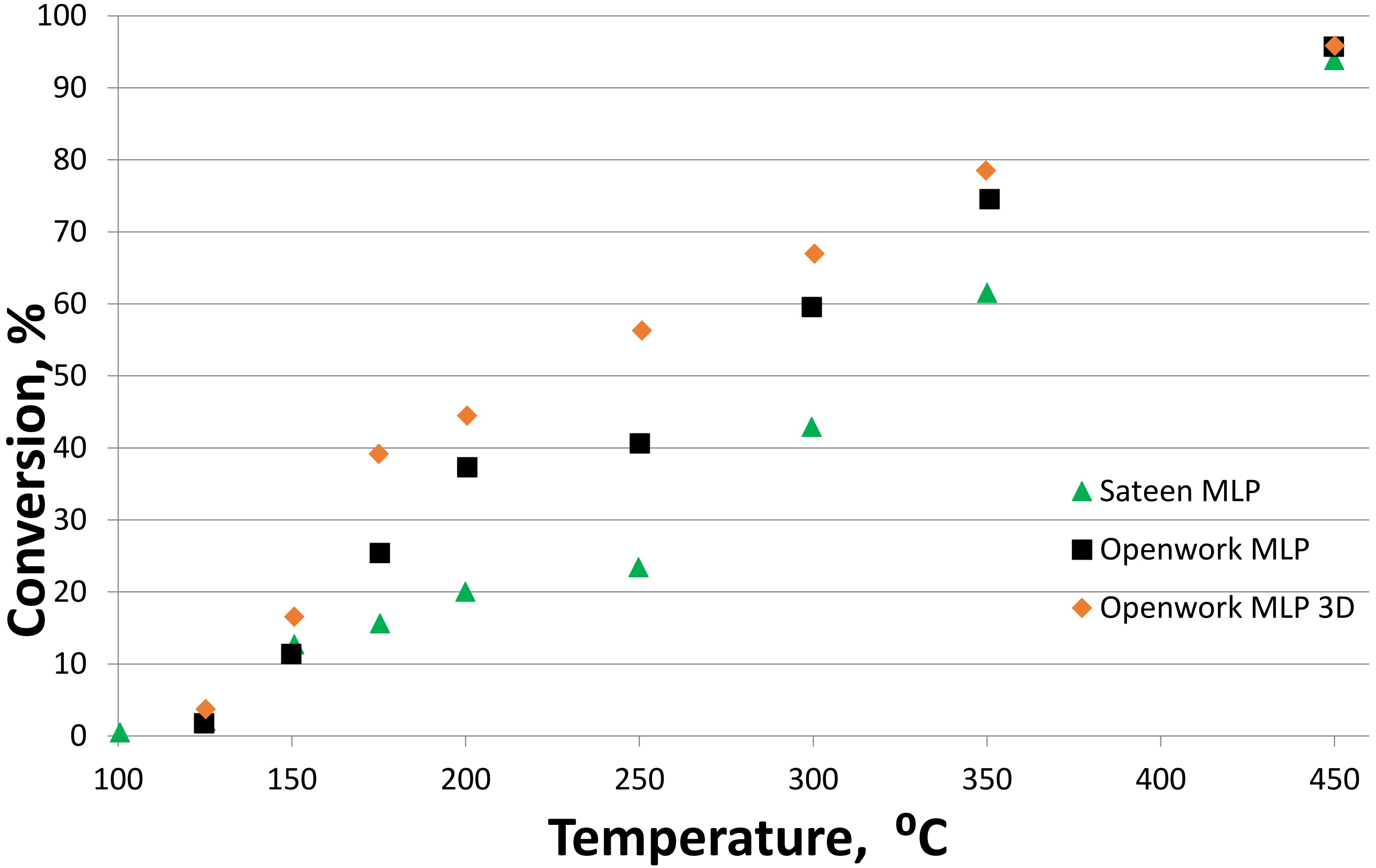
- With the arrangement of the fabric layers longitudinally to the flow, the Sateen sample showed the highest apparent activity, the sprayed sample showed the least activity, and the IC-12-S102 sample occupies an intermediate position.
- It should be taken into account that the content of platinum, as shown above, in the presented samples: 0.08, 0.02, 0.03%, respectively.

Comparison of MLP and longitudinal flow samples



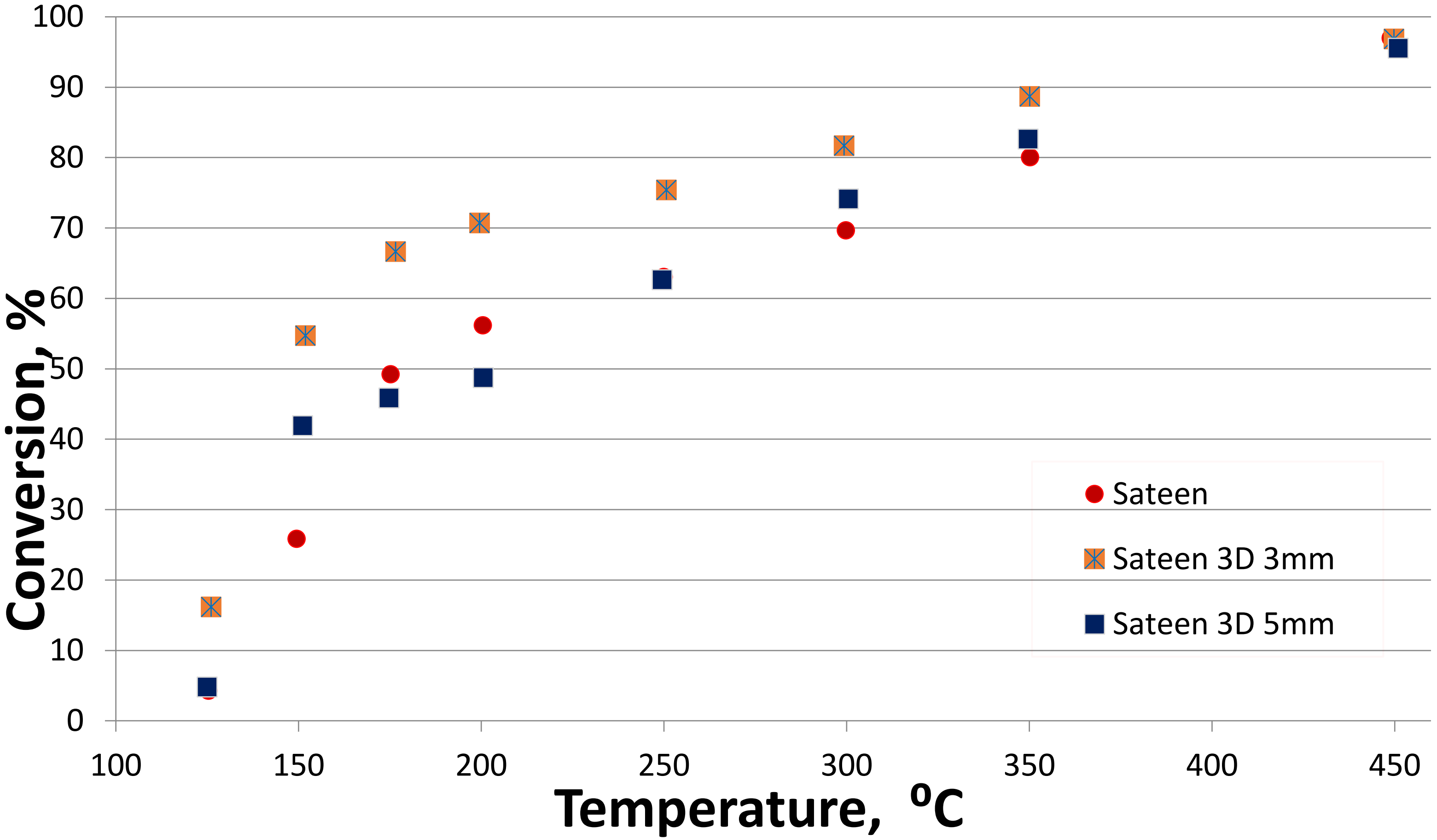
- The plot shows that with the longitudinal catalyst packing, the openwork weaving is inferior in activity to sateen weaving.
- However, MLP packing exhibited a significantly reduced activity of sateen weaving, since the catalyst layers overlapping each other has high pressure drop, thus forcing the reaction flow to find local passages with increased permeability, deteriorating the access of the reactants to the part of the catalyst surface.

Comparison different of samples with MLP



- This plot compares layered packing types. Again, sateen MLP is seen to be the least active. The openwork MLP sample showed higher activity due to the higher flow permeability and better uniformity of flow distribution in the GFC packing
- It should be noted that when the 3D mesh is located between the catalyst layers (openwork MLP 3D sample), the activity grows due to an additional increase in access to the active component and more uniform distribution of the flow across the layers

Comparison of the apparent activity of cartridges with different channel heights and different structuring elements



- With a longitudinal arrangement of channels and a height of 5 mm, the 3D mesh exhibits an activity comparable to structuring by corrugated mesh a cartridge; at the beginning, the kinetic region is even slightly higher.
- The sample structured with a 3D mesh with a channel height of 3 mm showed the highest observed activity among all the samples studied.

Conclusions

Analyzing all the presented conversion charts, we can draw the following conclusions:

- The catalyst activity is influenced by both the methods of applying the active component and the quantitative content of platinum
- Longitudinal packing is more beneficial than the transverse packing. However, in multi-layered packing (MLP), the use of structuring elements has a positive effect on catalytic activity
- Placement of intermediate mesh layers in the openwork MLP 3D sample leads to higher apparent activity comparable to that in longitudinally packed cartridges due to the redistribution of flows, and this method is of interest for further research
- The lace weave in MLP structure is preferable due to its greater permeability
- Multilayer packing of the sateen type with is less advantageous because of the high hydraulic resistance, at which the reaction mixture finds local passages thus leading to less uniform distribution of the fluid across the catalyst layers
- It is noticed that the geometry of the channel also affects the mass transfer. At a channel height of 5 mm, cartridges with structuring elements in the form of a 3D mesh and corrugation exhibit comparable apparent activity. The activity increases significantly when using a 3mm 3D mesh due to more intensive external mass transfer in the cartridge

References

A.N.Zagoruiko, S.A.Lopatin. Structured Glass-Fiber Catalysts. Francis & Taylor group, CRC Press, 2019, 158 p., https://doi.org/10.1201/9780429317569

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