Izak Nieuwoudt,
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discusses the ways in which the microscopic and macroscopic geometric variables of structured packing can be used to design a packing with the desired efficiency and capacity.

PACKED FOR OPTIMAL *performance*

Distillation, absorption and stripping processes require the use of mass transfer devices to provide good contact between the liquid and vapour that flows countercurrently in towers. The early 1800s saw the introduction of bubble cap and sieve trays. During the second half of the 1800s, various types of random packing elements started to find application in these towers. The quest for lower holdup, improved efficiency and lower pressure drop led to the development of structured packing. In 1907, a form of structured packing was proposed.[1] The inventor claimed the following of his device: 'The invention is intended to secure the highest degree of efficiency in the absorption of vapours or gases by liquids...'[1] In 1935, a patent application was filed[2] for structured packing that was not too dissimilar to the sheet metal structured packing that was introduced in the 1970s.[3] The inventor of the 1935 patent application claimed: '...maximum contact between liquid and vapour, including the factor of extended area, as well as that of as active a surface as possible... the column should retain a minimum amount of liquid... and should give a minimum of back pressure.'[2] Since the late 1970s, structured packing became the mass transfer device of choice for systems with low liquid rates requiring low liquid holdup and/or low pressure drop. Applications such as ethylbenzene styrene and refinery vacuum towers benefitted tremendously from the use of structured packing, since it offered reduction in pressure drop and increased capacity. During the 1980s, a significant amount of research in the field of structured packing was devoted to developing innovative surface texturing to improve the liquid spreading and mass transfer efficiency.

Pushing the envelope

Mike Lockett found a way of circumventing the problem of liquid getting trapped at the horizontal plane where structured packing layers are in contact. Through careful

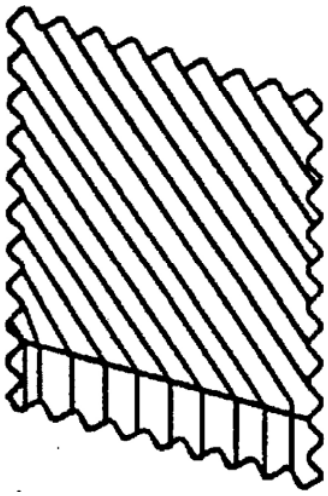

Figure 1. Example of a structured packing sheet with edge modification.[4]

experimentation, it was proven that modification of the edge of a packing element could extend the capacity of structured packing. Lockett was the first to file a patent application[4] for modifications to the edge of structured packing elements. This innovation formed the basis of FLEXIPAC® HC™ high performance structured packing. This new development raised several questions:

- Does this edge modification impact only the flood point, or are other performance parameters also affected?
- How can the microscopic and macroscopic geometry of structured packing be manipulated to get certain performance parameters?

This article explains the interplay between the geometric variables and their influence on packing performance.

Modifying the edges of structured packing

The edge modification proposed by Lockett turns the flow channel of the structured packing from an inclined channel to a vertical channel. This transition could be abrupt, slightly rounded or a sweeping arc, and the height of the vertical piece could be any percentage of the packing element height. One embodiment of such an edge modification is shown in Figure 1.

The influence of making the inclination angle of the flow channel steeper at the edge of the packing can be explained in Figure 2. As the inclination angle approaches the vertical, the efficiency decreases but the capacity increases. This is well accepted in industry, since the performance of the X (60˚) and Y (45˚) styles of packing have been known for several decades. This means that any vertical edge on a packing element would have a lower efficiency than the inclined part of the packing. If these vertical edges take up a large percentage of the element height, it is clear to see that the efficiency of the element as a whole would be decreased. From an efficiency point of view, it is thus important to note what percentage of the element height is taken up by vertical edge modifications. Packing with a large percentage of the element height devoted to edge modifications is inevitably going to be at an efficiency disadvantage.

Influence of packing geometry

Microscopic geometry

As was noted in the 1935 patent application,[2] it is important to get good contact between the liquid and the vapour, and to have as active an area as possible on the liquid film. What this means is that a packing that spreads the liquid evenly in a thin film and mixes the film will exhibit better performance than a packing that does not. Over the last three decades, the texturing of the packing surface was modified to improve the liquid spreading. This led to improvement in the packing efficiency. This is demonstrated in Figure 3 where the efficiency of two packings is compared, the only difference being the surface texturing. It is evident that the changes in efficiency due to surface texturing could be significant, and could mask the effect of changes to the edges, or other geometric changes.

Macroscopic geometry

As is shown in Figure 2, the inclination angle has a significant effect on the efficiency and flooding capacity of structured packing. Other geometric variables of the structured packing can also be used to affect the packing performance.

Putting it all together

Using the original structured packing developed in the late 1970s as the benchmark and invoking the facts given above, the following progression could be made:

- The original packing has a 45˚ inclination angle, no modifications to the packing edges and a first generation surface texturing. The efficiency and capacity of this packing are considered the baseline values.
- By adding edge modifications to the packing, the capacity of the packing is increased. The percentage of the packing element height devoted to the vertical edge modifications will determine what impact it has on the efficiency of the packing. The bottom line is that there will be some efficiency loss and that it will be exacerbated by making the edge modifications very tall. Compared to the baseline, this leaves a packing with increased capacity, but some reduction in efficiency.
- Improving the surface texturing on the packing with the edge modifications will improve the efficiency without affecting the capacity. This yields a packing with a better efficiency and capacity than the original packing. It has to be remembered that the surface area (m^2/m^3) is still the same.
- The influence of the crimp angle can now be invoked to further modify the packing to get the desired capacity and efficiency. Take the packing that has better efficiency and capacity than the baseline packing. By increasing the inclination angle, the efficiency of the packing is reduced, but the capacity is increased (Figure 2). The inclination angle can be changed to the point where the efficiency is the same as that of the baseline packing but with a significantly higher capacity. By using the combined effect of the surface texturing, inclination angle and edge modification, while keeping the surface area (m^2/m^3) constant, it is thus possible to produce a packing that has the same efficiency as the original packing, but provides significantly higher capacity. A packing with this combination of features offers the following benefits: In the case of a retrofit, the users will thus be able to get the same separation efficiency that they have been used to, but get a significantly higher throughput through the tower. In the case of a new tower, the added capacity could be used to shrink the tower diameter.

From Figure 2, Figure 3 and the discussion above, it is evident that the microscopic and macroscopic geometric variables of structured packing can be manipulated to produce a packing that either has the same capacity and better efficiency or has the same efficiency and better capacity.

A recent article[5] discussed how the shape of the edge modification impacts the performance of the packing. No mention is made in this article as to whether the packings that were compared had the same surface texturing and the same inclination angle. One of the packings in the comparison was from Koch-Glitsch, and the surface texturing of this packing was the original style that dates back to the late 1970s. To test the statement regarding the influence of the shape of the edge modification, Koch-Glitsch built packing with the following features:

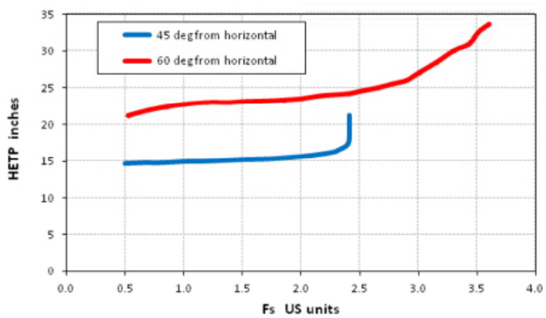

Figure 2. Efficiency and capacity comparison of two packings with the same surface area and geometry, but different inclination angles.

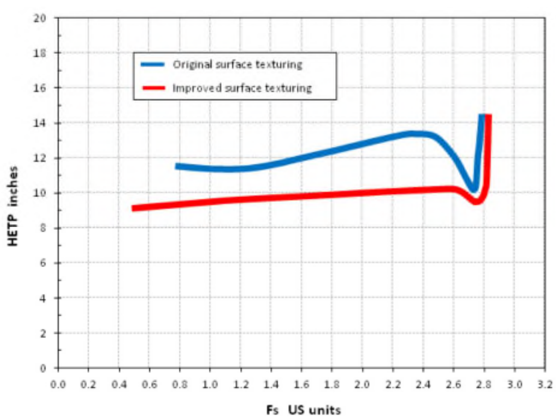

Figure 3. Influence of surface texturing on the performance of structured packing.

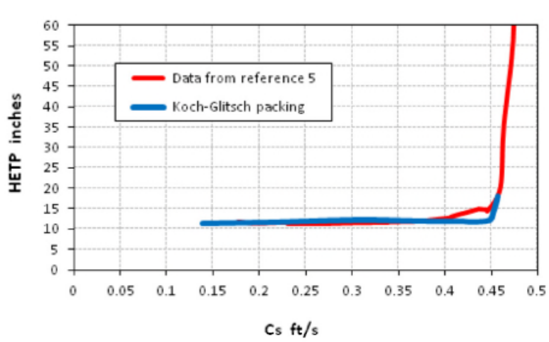

Figure 4. Efficiency comparison between two packings with differently shaped edge modifications.

- The latest surface texturing was used.
- A geometry (angles, etc.) was chosen based on the discussion in this paper.
- The HC™ edge modification from Koch-Glitsch was used.

In Figure 4, the performance of this packing is compared to that of the packing not from Koch-Glitsch in Reference 5. It is evident that the shape of the edge modification has no special impact on the packing performance. This test by Koch-Glitsch confirms that the reality is that, for structured packing with the same general geometry, performance is driven by the interplay between the geometry, having an edge modification and the surface texturing.

As pointed out in an earlier publication,[6] the performance of a tower is not only a function of the packing performance, but is also dependent on multiple factors. Special care has to be taken in the design of the distributors, inlet piping, vapour inlet devices, liquid collectors, and the installation of the equipment. The literature has numerous case studies[7] of towers that did not work as expected, but the performance shortfall was not caused by, nor linked to, the packing.

Conclusion

In this article, it is shown how the microscopic and macroscopic geometric variables of structured packing can be used to design a packing with the desired efficiency and capacity. In summary of the above analysis and testing, the following guidelines will help the user understand the impact of the variables:

- Adding edge modifications increases the capacity of structured packing.
- The taller the edge modifications relative to the height of the packing element, the more of a detrimental effect it has on the packing efficiency.
- The shape of the edge modifications has virtually no effect on the packing performance.
- A steeper inclination angle of the flow channels on the packing sheet yields a lower efficiency and a higher capacity.
- Improved surface texturing will improve the efficiency of structured packing relative to the 'original' surface texturing.

When designing for optimal performance in a packed tower, it is important to not focus solely on the packing performance. Suboptimal performance could also be a result of problems with the distributors, inlet piping, liquid collectors, vapour inlet devices or poor installation. To ensure good tower performance, a holistic approach that includes all these factors needs to be adopted.

Note

FLEXIPAC is a trademark of Koch-Glitsch, LP and is registered in the US and various other countries. HC is trademark of Koch-Glitsch, LP and is registered in the US.

References

1. US patent 899,899 *'Filling material for reaction chambers'*, Filed 26th Septrmber 1907.
2. US patent 2,047,444 *'Packing for fractionation columns and the like'*, Filed 14th January 1935.
3. US patent 4,296,050 *'Packing element for an exchange column'*, Filed 12th May 1977.
4. US patent 5,632,934 *'Packing with improved capacity for rectification systems'*, Continuation of application filed on 4th October 1994.
5. PILLING, M., *'Packed and loaded'*, Hydrocarbon Engineering, July 2012, pp. 89 – 92.
6. ENDER, C., COPP, M., NIEUWOUDT, I. and QUOTSON, P., *'Improving packed tower performance'*, Hydrocarbon Engineering, July 2006, pp. 51 – 54.
7. KISTER, H.Z., *'What caused tower malfunctions in the last 50 years?'*, Trans IChemE, Vol 81, Part A, January 2003, pp. 5 – 26.