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EUROPEAN ROADMAP OF PROCESS INTENSIFICATION

- TECHNOLOGY REPORT -

TECHNOLOGY:
Structured Internals for Mass Transfer Operations

TECHNOLOGY CODE:
1.1.3.

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1. Technology

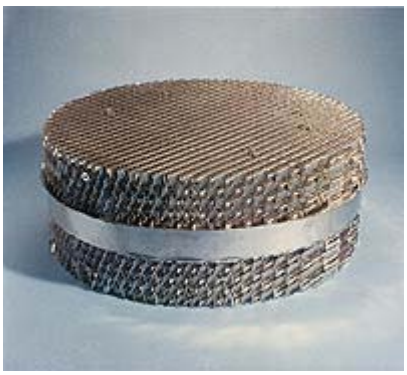
1.1 Description of technology / working principle

Structured internals are made of vertical sheets of corrugated thin gauze / metal / ceramic / glass/ plastic with the angle of the corrugations reversed in adjacent sheets to form a very open honeycomb structure with inclined flow channels and a relatively high surface area. Those internals are applicable for liquid/liquid mixing, generally in co current flow and for liquid/gas mass transfer in counter current film flow. If liquid and vapour phases are involved, the liquid descends in the form of films distributed over the packing surface, and the vapours rise through the spaces between the packing particles. Structured internals may be used in static mixers, in distillation and extraction columns, in reactors and in hybrid processes combining different unit operations.
In this report counter current liquid/gas mass transfer without reaction is described. For liquid/liquid mixing equipment the reports 1.1.4 “static mixers” and 1.1.5 “micro mixers”, for hybrid processes report 2.2.8.1 “reactive distillation” should be taken as references. In addition the different reports on reactor technology (1.2.1.2, 3.2.4, 3.3.3.4.1, 3.3.3.4.2) may provide for some information on mass transfer in structured packings with reaction. The role of structured packings in extraction may be seen in reports 2.2.5 and 3.3.1.1, some overlap exists to report 2.1.3 “extractive distillation”.

The main field of application are distillation columns. In general, packing works best at low liquid flow. The low pressure drop and the high separation efficiency of structured packing makes it very attractive for use in vacuum columns and in difficult separations.

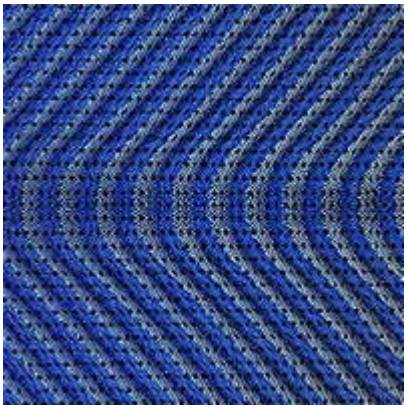
1.2 Types and “versions”

Structured packings for liquid/gas processes are introduced into the market in different types: The differences between the packing versions are the form and the dimensions of the gas channels, the inclination of the channels, the gas bypasses between the channels and many other construction details that offer a great variety of technical goals measured in gas load, liquid load, pressure drop and separation efficiency as performance parameters. Designs adapted to every special application are possible.

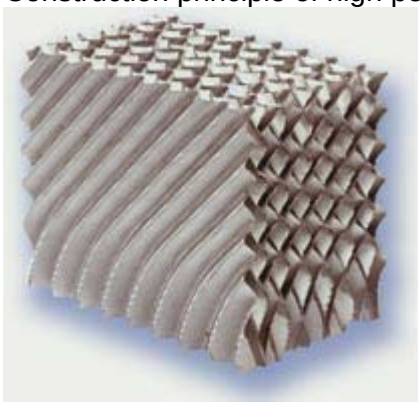


Example for a conventional packing made of corrugated metal sheets (Kühni Rombopak)

The new types of the technology under consideration in this report are a modification of the conventional types, not a completely new construction. This modification avoids flooding effects in such packings at the edges where different packing elements meet.



Construction principle of high performance packings (Sulzer Mellapak Plus)



Example for a high performance packing (Montz-Pak Type M)

The effects of this modification together with optimisation of the other parameters are surprisingly high, 20 – 40 % higher capacity or advantages in pressure drop or separation efficiency depending from the special design.

1.3 Potency for Process Intensification: possible benefits

The basis of the comparison with existing technology, especially for the magnitudes of the benefits are the respective best values for conventional trays, random packings or conventional structured packings. The magnitude of the benefits refers to mean values of the new modified types of packings and their advantages compared to the best solution of the conventional technologies.

Table 1: Documented and expected benefits resulting from technology application

Benefit	Magnitude	Remarks
Higher gas load = higher throughput	Up to 140% compared to conventional equipment	Design has to be adapted to the goal: High load factor with HETP's in the usual range.
Low height of a theoretical stage (HETP) = high separation efficiency	Down to 70 % compared to conventional equipment	Design has to be adapted to the goal: Low HETP with gas load in the usual range.
Low pressure drop per theoretical stage = smaller temperature difference over the column	Down to 70 % of the pressure drop of conventional equipment	Design has to be adapted to the goal: Low pressure drop with gas load in the usual range. Low HETP's remain possible.

Investment savings	Savings of 20 % of the investment compared to conventional equipment	Design has to be adapted to the goals: either higher load or lower pressure drop or low HETP or an optimization over all these parameters.
Energy savings	20 % savings compared to conventional designs	Savings in the case of a low HETP design, that means more theoretical trays for a given height of a column: energy savings by lower reflux ratio.
Lower temperature level of energy input	Up to 20 Kelvin lower are possible for a design with low pressure drop	Lower temperature is more favorable for heat integration, in the case of direct heating a lower vapor pressure stage may be possible.

1.4 Stage of development

As stated before, structured internals are introduced in the market as one type of standard equipment. The recently modified types of the technology under consideration entered the market during the last few years and in the meantime are offered from all major suppliers. The remarkable advantages of these packings are not yet commonly accepted because the prices of these internals are higher than for conventional equipment.
In addition the base case for a comparison of new or modified structured internals with conventional internals is a moving target. Column trays for example are continuously improved to “high performance trays” and the same is true for random internals. So, actually the new generation of structured high performance packings seems to be the most powerful solution for most of the separation problems. Nevertheless, the market develops for any product and has to be observed thoroughly.

2. Applications

2.1 Existing technology (currently used)

Different equipment is well introduced as internals for mass transfer. Many suppliers offer a wide range of different constructions. Types of internals are trays of different types with or without downcomers, random packings in various shapes, conventional structured packings and other internals like grids. The parameters characterising mass transfer internals are maximum gas and liquid loads, stable load ranges, separation efficiency, pressure drop and special features like fouling and polymerisation resistance. The different types of internals can be adapted by variation of the many design parameters to all operating conditions that are technically interesting. Conventional structured packings are mainly used for low liquid loads, vacuum separations, difficult separation problems (need for high numbers of theoretical stages).

A problem of conventional internals is that high demands with respect to one of the design parameters are connected with weaker values of the other parameters. For example a high separation efficiency in general is possible only for low vapour loads, the same is true for low pressure drop.

Further problems are the operating limits in the case of revamps of existing plants. The existing internals normally are operated at the limit of the allowed load range. More efficient equipment with a higher maximum load range or a better separation

efficiency may allow to increase capacities, to reach higher purities or to save energy by changing the internals without changing the compartment, the column.

2.2 Known commercial applications

Table 2. Industrial-scale applications of the Technology (existing and under realization)

Sector	Company - Process/Product name/type	Short characteristic of application	Production capacity /Plant size	Year of application	Reported effects
Petroche-micals	all major companies	distillation, extraction	more than 100000 t/yr	growing	Smaller column diameters, lower column heights, energy savings
Bulk chemicals	all major companies	distillation, extraction	5000-200000 t/yr	running	Smaller column diameters, lower column heights, energy savings
Fine chemicals	all major companies	distillation, extraction	500-5000 t/yr	growing	flexible equipment, low hold up
Pharma-ceuticals	all major companies	distillation	<500 t/yr	growing slowly	flexible equipment, low hold up

2.3 Known demonstration projects

Table 3. Demonstration projects related to the technology (existing and under realization)

Sector	Who is carrying out the project	Short characteristic of application investigated, including product name/type	Aimed year of application	Reported effects
High perfor-mance structured internals		Mass transfer gas/liquid		No project known, developments are mainly by internal research of suppliers

2.4 Potential applications discussed in literature

The new generation of structured internals is applicable (like the conventional ones) for all stable chemicals, including high capacity plants, for vacuum distillations, for difficult separations which need a large number of theoretical stages.

Advantages for the new internals exist especially for temperature sensitive products, may be chemicals, pharmaceuticals or food. Here the application range may be widened to chemicals that tend to cracking, to fouling or to polymerisation under the conditions of a distillation: The lower pressure drops and/or the higher separation efficiencies of the new generation of structured internals may allow more favourable conditions with respect to temperature and residence time.

So, on the one hand the modified structured internals give the opportunity to optimize existing processes or plants significantly, on the other hand the superior properties of the new internals may allow to design separations that are not possible with conventional equipment.

3. What are the development and application issues?

3.1 Technology development issues

The good properties of the modified internals may still be improved by further modifications of the geometry, by totally new structures leaving the basic principle of folded sheets or by introducing additional forces like electrical, gravitational or sound fields.

Table 4. Technology development issues

Issue	Description	How and by whom should be addressed?
better separation efficiency	modified geometry, new structures	suppliers
better separation efficiency	additional forces like electrical, gravitational or sound fields.	universities
lower pressure drop	modified geometry, new structures	suppliers
higher gas and/or liquid load	new structures	suppliers
higher gas and/or liquid load	additional forces like electrical, gravitational or sound fields.	universities
lower hold up	new structures	suppliers

3.2 Challenges in developing processes based on the technology

There are some fields of application where structured packings till now are not applicable.

Table 5. Challenges in developing processes based on the technology

Challenge	Description	How and by whom should the challenge be addressed?
Systems with higher viscosity	film flow and mass transfer properties become unfavorable, modified geometry could be helpful	suppliers and/or universities
Polymerizing systems	polymerization leads to blockings, sharply reduced residence time (new geometry) could contribute to solve the problem	suppliers
Systems with fouling tendency	fouling leads to blockings, modified geometry with constantly wetted surfaces could be helpful	suppliers

4. Where can information be found?

4.1 Key publications

Table 6. Key publications on the technology

Publication	Publication type (research paper/review/book/ report)	Remarks
Olujic, Z., , Kaibel, Jansen,H., Rietford,T., Zich,E., Frey, G.,, Distillation Column Internals /Configuration for Process Intensification, Chem.Biochem.Eng.Q.17(4) (2003) 301-309	Research paper	Presentation of new structured packing
Billingham, J.F., Lockett, M.J., Development of a new generation of structured packings for distillation, Trans IChemE, 77 (1999) 583-587	Research paper	Presentation of new structured packing
Gorak, A., Hoffmann, A., Catalytic Distillation in Structured Packings: Methyl Acetate Synthesis, AIChE Journal 47 (2001) 1067-1076	Research Paper	Structured Packings in Reactive Distillation
Besson, G., Propriétés et charactéristiques des garnissages pour colonne d'absorption, information chimie no 178 – spécial juin 1978, 237	Research paper	Structured packings in absorptions
Fair, J.R., Seibert, A.F., Behrens, M., Sarabeer, P., Olujic, Z., Structured Packing Performance-Experimental Evaluation of Two Predictive Models, Ind. & Eng. Chem. Res. 39 (2000) 1788-1796	Research paper	Comparison model and experiment
Bender, P., Moll, A., Modifications to structured packings to increase their capacity, TransIChemE, Part A, Chem.Eng.Res.Des. 81, 58 (2003)	Research Paper	New packings
Parkinson, G., Drip and Drop in Column Internals, Chem. Eng., July 2000, newsfront, 27-29	Report	New type of packings
Schultes, M., Füllkörper oder Packungen? Wem gehört die Zukunft?, Chem. Ing. Techn. 70 (1998) 254-261	Review	
Spiegel, L., Meier, W., Distillation Columns with structured packings in the next decade, TransIChemE, Part A, Chem.Eng.Res.81, 39 (2003)	Review	
Stichlmair, J.G., Fair, J.R., Distillation Principles and Practice, McGraw-Hill, New York (1998)	Book	Design of columns
Ludwig, E.E., Applied Process Design Vol. 2, Butterworth-Heinemann / Gulf Publishing	Book	Design of columns with structured packing
Each of the major suppliers offers reviews on the performance properties of the packings he sells.	Reviews	From the internet or on demand

4.2 Relevant patents and patent holders

Table 7. Relevant patents

Patent	Patent holder	Remarks, including names/types of products targeted by the patent
DE10327986	M.PORE GMBH	static mixer, for mixing streaming
EP0827777	KOJIMA H	Gas-liquid processing apparatus
EP1029588	SULZER CHEMTECH AG	Filler body for a packing column in heat/mass exchange
EP1354863	HALDOR TOPSOE AS	Continuous drying of hydrocarbon stream
EP1522337	LINDE AG	Evaporating cryogenic liquid
US2002063344	PAGADE P K	Contact enhancing device for heat exchange equipment
DE10124386	BASF AG	Distillation column for mixtures
DE10208711	BASF AG	Catalytic ceramic packing used in column
EP1440730	BASF AG	Packing, for reactive separation column
NL1009499C	DSM NV	Column for subjecting a gas or liquid to a physical separation process

4.3 Institutes/companies working on the technology

Table 8. Institutes and companies working on the technology

Institute/Company	Country	Remarks
University of Delft	The Netherlands	Properties of structured internals, development of monolithic structures
University of Twente	The Netherlands	Properties of structured internals
University of Dortmund	Germany	Simulation of the flow hydrodynamics, internals including reactions
Technical University of Berlin	Germany	Residence time, starting procedures
University of Austin/Texas	USA	Properties of structured internals
Suppliers		Each supplier does research to improve the technology

5. Stakeholders

5.1 Suppliers and developers

Table 9. Supplier and developers of structured packings

Institute/Company	Country	Remarks
Sulzer Chemtech	Switzerland	Metal and polymer packings
Kühni	Switzerland	Metal packings
Raschig	Germany	Metal packings
Montz	Germany	Metal packings
QVF Engineering	Germany	Glass packings
Koch-Glitsch	USA	Metal and ceramic packings
Yogi structured packagings and engineering	India	Metal packings
AceChemPack Tower Packing	China	Metal and ceramic packings

5.2 End users

End users are or may be (as stated above) all producers of petrochemicals, chemicals, pharmaceuticals.
In addition food producers may profit from the technology (low residence time, small hold up), Pulp and Paper for the make up of recycle streams, energy producers for washing towers and for future technologies for CO_2 capture. Industrial applicants of lakes or coatings may be end users for solvent recovery.

6. Expert's brief final judgment on the technology

Structured internals are largely used in the chemical industry. The new modified packings with remarkable advantages compared to the established internals have the potential to optimize processes in the chemical industry and to widen the application range of structured internals. In addition other than the introduced users may profit from the performance of these new packings.
Nevertheless it has to be stated that the development of separation internals is not restricted to structured packings, other internals may come to a similar performance.