Sophisticated Filters Rotate!

The separation technique dynamic cross-flow filtration is enjoying ever greater recognition in the field of membrane filtration. This article provides an overview of the unique selling points of this sophisticated method and the resulting applications.

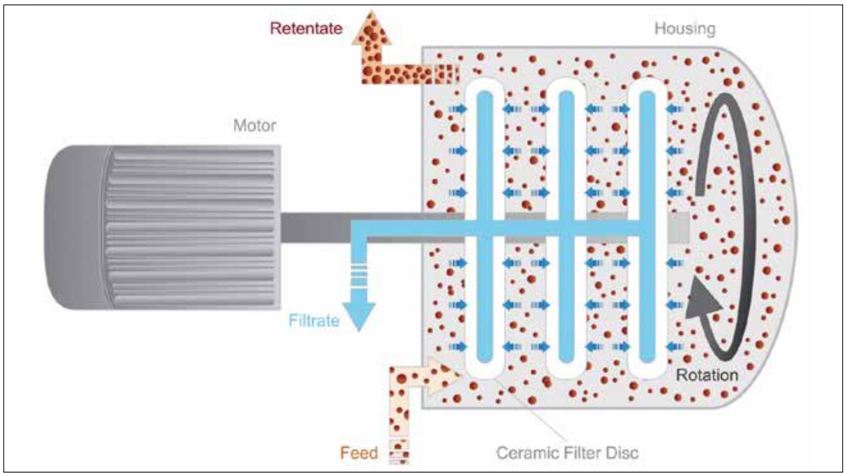

Fig. 1
Schematic representation of a setup for DCF

1 Introduction

The requirements on both a membrane and a filtration setup are becoming ever greater. The comparably higher price for a ceramic filter is justified by the resilience on thermal and chemical stress, higher flux due to hydrophilicity and extended service life. Since continuous production with high throughput is crucial for profitability and competitiveness, cross-flow filtration setups have become standard in many industrial branches. The tangential flow (cross-flow) of the feed along the membrane surface induces shear forces which help to contain the growing filter cake and creates a plateau of the flux over time. In reality, however, particle size distribution, compressibility and stickiness of the retentate quickly lead to a dense top layer with insufficient permeability. Further cleaning procedures, namely backwashing and cleaning in place, as well as procedural skills help to raise the overall flux to a higher level. Though, the basic issue remains: The cross-flow velocity is coupled to the Transmembrane Pressure (TMP). Even though (single- or multi-channel) tubular membranes are able to generate high velocities, in the end the applied pressure is the limiting factor. High viscosity or sensitive retentate need a moderate TMP to be concentrated any further. Another throwback of this setup is the uncontrolled shift of the TMP within the membrane surface due to the gradual formation of a filter cake along the tube.

Keywords
ceramic membrane, cross-flow, dynamic filtration, high flux

2 Dynamic cross-flow filtration and its benefits

A setup, which is called dynamic cross-flow filtration (DCF) or rotation filtration, solves this issue (Fig. 1). Disc-shaped ceramic membranes are assembled onto a hollow shaft for filtrate drainage. This stack is rotated by a motor to generate the cross-flow velocity in a pressurised housing with quasi-static feed. The filtrate passes the membrane from the outside to the inside while the retentate is either concentrated at closed outlet or re-cycled (diafiltration). Consequently, the cross-flow velocity is now fully decoupled from TMP and can be increased many times over. Having rotational speed and pressure as individual parameters is crucial for process engineering react to the ever-changing physical properties of the unfiltrate side. The optimisation is not limited to only tailoring these parameters, though, but starts already in the orientation and arrangement of the membrane stacks. Depending on the individual application, horizontal or vertical construction can be preferable. Beyond that, turbulence can be modified by the choice of a single or multiple shafts within a module. Overlapping discs in the latter setup even override motor or plant-specific limits in cross-flow velocity: The speeds of discs rotating in the same direction add up in the overlapping area and thus maximise the cross-flow velocity on the membrane surface (Fig. 2) [1]. The DCF combines several advantages which give this method a high added value and make it outstanding for intricate application: Gentle filtration of highly viscous material at comparatively high flux and low specific energy consumption becomes possible. A comparative study on multichannel tubes and a rotating system has shown that specific energy costs can be reduced by almost 90 % (Tab. 1) [2].

3 Using the benefits: possible applications

These benefits open up a wide range of possible applications for DCF. The combination of ceramic membranes with the sophisticated rotation filtration method can be applied wherever the requirement for resilient and traceless setups meets challenging feeds. Such challenges include sticky,

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Tab. 1
Comparison of the costs using a multichannel and a rotating disc module, respectively, for filtration of a low-viscosity test liquid [2]

	Multichannel Module	Rotating Disc Module
Specific running costs	8,85 EUR/m³	4,86 EUR/m³ (–45 %)
Specific energy costs	4,80 EUR/m³	0,67 EUR/m³ (–86 %)
Relative invest costs	1,00	1,17 (+17 %)

sensitive or stably dispersed materials that must be washed, separated, or collected as effectively as possible. Therefore, the technique has been successfully implemented in the following applications (Fig. 3).

3.1 Waste and process water

Although space requirement in this field usually is of secondary importance and mostly cheap and simple (e.g. submerged flat sheet membranes) setups are chosen, the DCF can score in this sector with its advantages. Whenever it comes to tough retentate or a thickening process, DCF gains in significance. For that reason, the technique is certainly more suitable for blackwater than for greywater, more suitable for sludge than for leachate, and so on. The same criteria also apply for process water; heavily loaded feeds are treated more economically with rotation filtration.

3.2 Lipophilic matter

The separation of lipophilic substances utilises two things of the rotation filtration with ceramic membranes. On the one hand the hydrophilicity of the material and on the other hand the gentle retentate treatment caused by the independently controllable TMP. This combination makes it feasible to split more or less well-dispersed emulsions, be it kitchen wastewater or produced water from oil industry [3].

3.3 Mining

Minerals from mining are treated manifold to obtain purified and specified granules from the raw material. Many of these processes take place wet and in suspension. The task of the DCF here can be to thicken these suspensions as far as possible. Since inorganic matter is not as sticky as organic substances, and therefore both the viscosity and the filter cake growth can be condemned particularly targeted by the motion of the particles, this type of feed is very grateful in filtration. The DCF can also be helpful later on when it comes to recovering the recyclables in the subsequent application. In this way, for example, the minerals from glazes in the ceramics industry can be recovered.

3.4 Chemical industry

The field of this industry extends over a strongly diverse variety, and so do the possibilities to use the DCF in this context. Chemistry is quickly associated with terms like toxic or corrosive, which is of course not always the case. Other focal points give rotation filtration a high added value here. Washing and concentrating of inorganic or organic pigments, colloids like latex particles or other dispersed material is only a few examples for products which can be treated with DCF. The technique also helps in areas where alternatives reach their limits. For example, graphene or graphene oxide represent dispersions that are difficult to separate by centrifuge due to their stability; it is no problem, however, for DCF.

3.5 Biotechnology

Working with microorganisms and enzymes as well as plant and animal cell cultures requires a great deal of sensitivity. Again, the decoupling of TMP and cross-flow velocity brings exactly this prerequisite. The pressure onto the bio systems can be kept uniform and low and these types of valuable materials can be softly harvested by rotation filtration.

3.6 Manure and digestate

Using manure and digestate as natural fertilizer is due to its great availability, the contained nutrients (nitrogen, phosphorus, and potassium compounds, often abbreviated to N-P-K), and the shortage of some

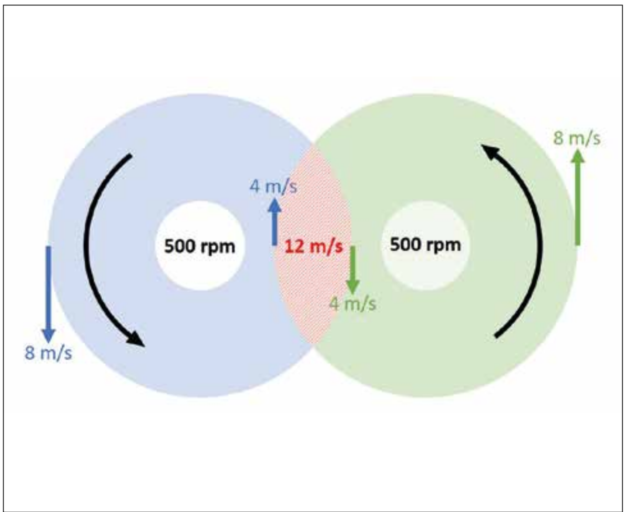

Fig. 2
Sketched illustration how the cross-flow velocity in the overlapping zone of a multi-shaft setup is increased

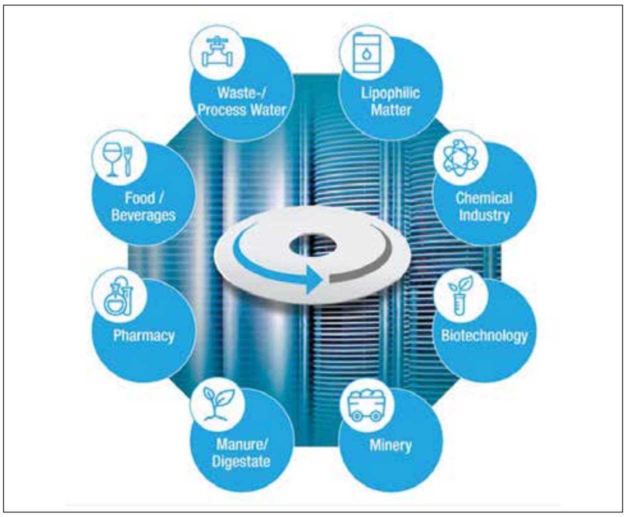

Fig. 3
Overview on possible applications for DCF

Fig. 4
Example for the high viscosity that can be obtained with DCF (red and white wine lees) [5]

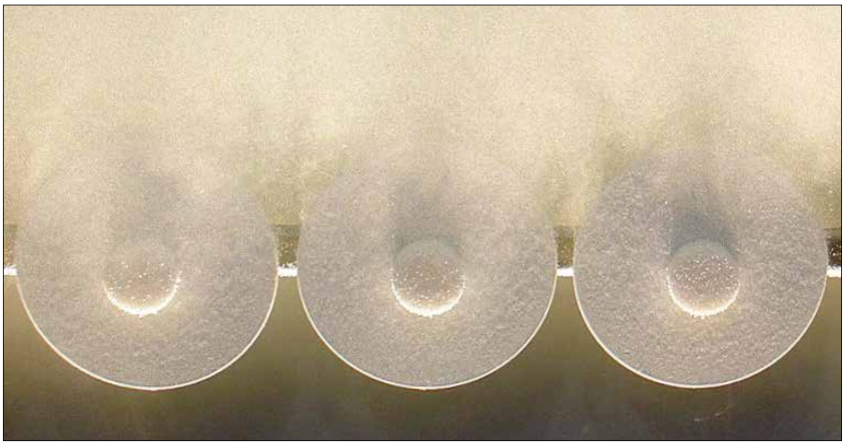

Fig. 5
Ceramic membrane discs working as gas diffusors

mineral fertilizers (especially phosphate) obvious and basically recommendable. The variety in composition of both manure of different livestock (cattle, pork, poultry, etc.) and digestate as well as the varying demand of agricultural plants (grass- and farmland, types of crops, etc.), however, rarely represents a well-fitting combination. After splitting up a solid phase (soil conditioner) with a screw separator, the ultrafiltration step separates a concentrate of phosphate. With the selection of a suitable pore size and pH control, it is also possible to separate ammonium in the desired ratio as well. A subsequent reverse osmosis step brings a concentrate of N-K fertilizer and large amounts of pure water [4].

3.7 Food and beverage

Ceramic has the property of not releasing any ingredients. There are no plasticizers or other substances that are harmful or modify flavour and would therefore restrict its use in the food and beverage industry. This allows a wide range of creation. The possibility to "squeeze the last drop" out of the retentate becomes clear in the beer/yeast recovery or in the wine filtration with a wine lees concentration at the end up to 99 vol.-% (Fig. 4) [5]. Dairy industry benefits in separation of bacteria or fractionation of casein and proteins. The retentate is also significant in the filtration of selected juices (e.g. carrot juice for dye extraction) or the production of concentrated tomato paste.

3.8 Pharmacy

There are not many areas where the requirements are even stricter than in the food and beverage sector. Pharmacy is one of them for sure. Besides the sterile conditions, controlled contact time and gentle product treatment are inevitable. Cells, proteins and other are sensitive matter which can be appropriately and effectively processed with DCF.

4 Summary and outlook

The setup realised in a dynamic cross-flow filtration plant combines several advantages that make this method, together with ceramic filters, an exceptional separation method with valuable unique selling points. The application overview has shown the massive potential of this technique, which is far from exhausted with the current markets. The possibilities start where other setups reach their limits. Incidentally, the rotation that underlies this sophisticated system is not only limited to filtration – using the ceramic membranes as gas diffusor is a direct and very effective way for gas input, which can be tuned in bubble size by rotation (Fig. 5) – sophisticated membranes rotate!

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