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Dynamic cross flow filtration

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Abstract

The dynamic cross flow filtration with the DYNO filter is a very versatile and economic high performance filtration process especially for suspensions with critical separation characteristics. Thickening, washing and clarifying of suspensions but also a classifying sieve filtration can be performed with the DYNO filter in a continuous operation with permanently high throughput rates. The principle of the dynamic high shear filtration ensures almost ideally physical conditions for the separation process. Contrary to classical cross flow filters a repeated recirculation of the suspension is not necessary for attaining the separation target. In the DYNO filter suspensions can be highly concentrated up to the flow limit in only one filtration cycle. In most cases, the concentrate is as dry as a firm filter cake and the filtrate is crystal-clear. Sieve filtration tasks for separating of coarse grain are performed with high concentration factors of up to 1000. Thus, the coarse fraction is obtained highly concentrated.

Keywords: Cross flow filtration; Thickening; Washing; Clarifying; Classifying

1. The principle of the dynamic cross flow filtration

The dynamic cross flow filtration with the DYNO filter stands out against conventional cross flow filtration by the following special process feature: in the DYNO filter, the typical tangential flow of the suspension over the filter medium is generated by rotors and not by the geometric flow conditions in the apparatus. This principle offers important process advantages. Since the distance between the filter medium and the rotors is very small the suspension is forced to a turbulent cross flow over the filter medium in a narrow slit. The high velocity gradient of this high shear cross flow prevents efficiently that solids form a deposit on the filter medium. Only an extremely thin layer of solids is formed with a very low flow resistance for the filtrate (Fig. 1). Simultaneously, the suspension is thoroughly mixed by the rotors which prevent layers of high solids concentration near the filter medium.

Therefore, the filtration velocity at the dynamic cross flow filtration with the DYNO filter is very high. The filtrate flow rates are two to ten times higher compared to the conventional cross flow filtration or compared to cake forming filters as shown in Fig. 2.

2. Construction and operation of the DYNO filter

The DYNO filter is build up of disc shaped filter modules which are arranged in series forming a completely closed process chamber system. Rotor and stator discs are the basic elements as shown in Fig. 3.

The stator discs are equipped with drainage channels for the filtrate and drillings for a wash water feed. They are covered with a filter medium, which is fixed with simple flanges on both sides. Two stator discs enclose a pressure tight filter chamber or suspension chamber, respectively. Round openings in the middle of the stator discs form the passage for the rotor shaft on which the rotors are mounted. The suspension chambers are connected through the ring shaped slits between the rotor shaft and the stator discs. These slits are designed for ensuring an unimpeded suspension flow from one chamber to the other.

The suspension is fed under pressure on the rotor drive side and flows meander-shaped between the stator discs and the rotor discs from one chamber to the next. The liquor passes the filter medium due to the acting pressure and is removed through the stator discs as particle-free filtrate. This way, the concentration of the suspension increases from chamber to chamber. Since the remaining suspension is thoroughly mixed by the rotors, which also prevent solids settling on the filter medium, there is a constant high filtrate flow even in chambers where the solids concentration is high. In the last chamber the thickened concentrate is discharged through a discharge valve. Since the suspension

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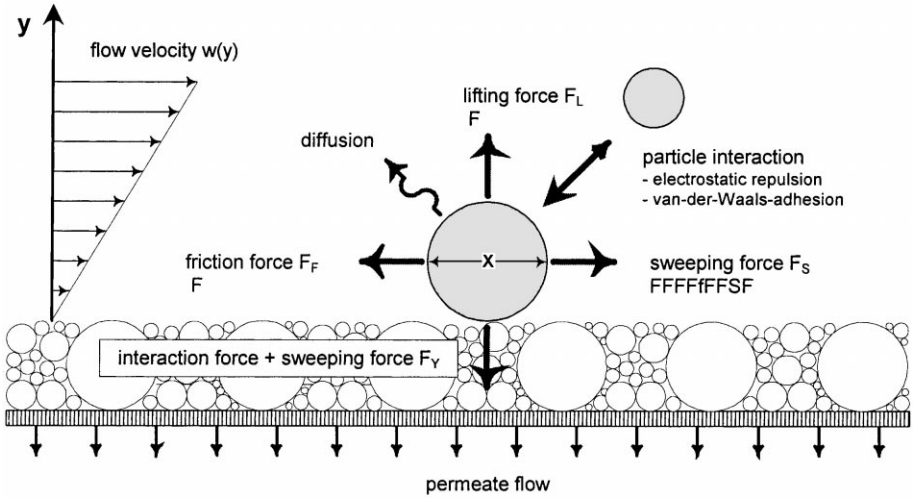

Fig. 1. Force balance on a particle at cross flow filtration.

is permanently sheared, the concentrate has a pasty consistence and is flowable even at high concentrations.

Due to the modular and compact construction, the DYNO filter has offers a large filter area and can be increased or reduced easily.

3. Control of the concentration

With increasing concentration of the solids the viscosity of the suspension also increases and the power consumption of the rotor drive grows accordingly. Due to this correlation, the power consumption can be used to control the filter operation. If the measured rotor torque has reached a certain set point, the discharge valve is opened through a control

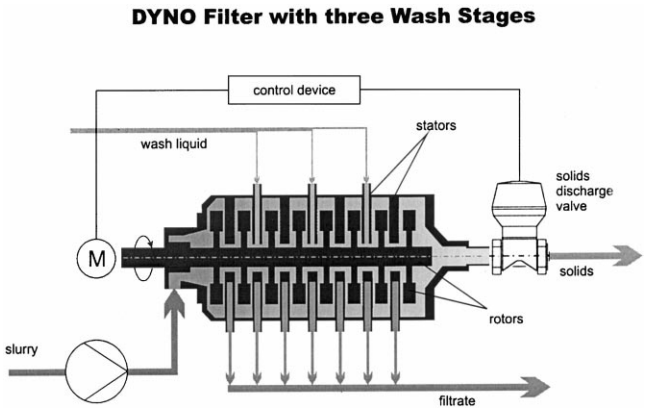

Fig. 3. DYNO filter with three wash stages.

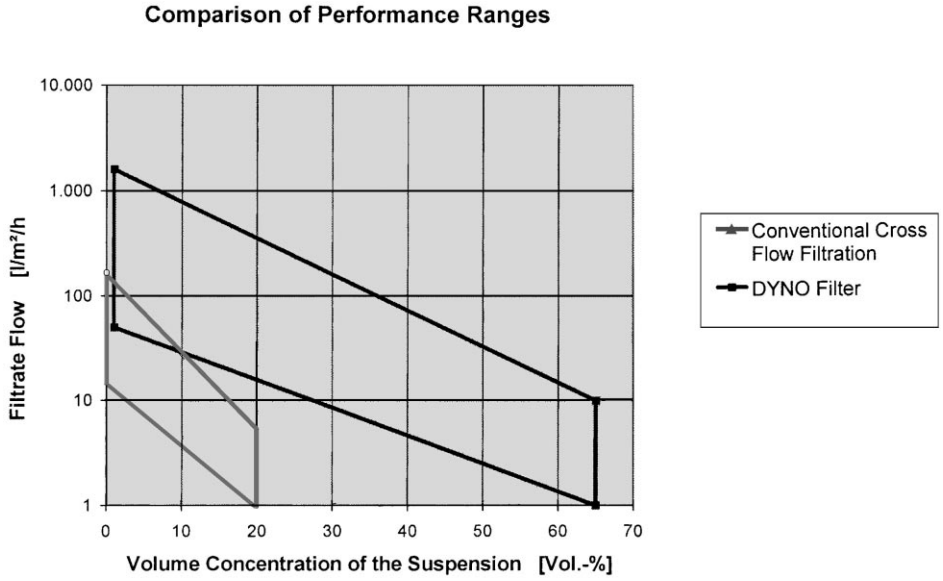

Fig. 2. Performance range of the dynamic cross flow filtration with the DYNO filter and of the conventional cross flow filtration.

system and the concentrate is discharged through the pressure in the filter chamber. Therefore, the DYNO filter works in many cases with quasi-continuous solids discharge, while both the suspension feed and the filtrate discharge is always continuous. By varying the set point, the concentration rate can be easily adjusted between low thickened and just flowable.

4. Filter media

In most applications, membranes with pore sizes of 0.01–1.0 μm (micro filtration) are used as filter media. The fine pores avoid a clogging or fouling of the filter medium and ensure an absolutely clear filtrate. The smooth surface of such membranes and the yield forces generated by the rotors allow only a thin boundary layer of solids particles which has a negligible filtration resistance, but which protects the membrane from mechanical abrasion. For special applications also ultra-filtration membranes can be used in the DYNO filter. For sieve filtration, special multi-layer wire cloths are well proved.

5. The strength of the DYNO filter-thickening, washing, liquid purification and sieve filtration

The dynamic cross flow filtration with the DYNO filter is a separation process which is excellently suited for suspensions in a wide range of product characteristics (Table 1). Suspensions with Newtonian flow behaviour as well as suspensions with viscous, intrinsic viscous or thixotrope characteristics can be thickened, washed, clarified or classified. The most economic results are obtained if the particle diameters lie in the range of 0.01–200 μm. This makes the DYNO filter suitable for applications in many industries and for the separation of different products like fine minerals, inorganic pigments, organic pigments, numerous products in the pharmaceutical industry and in the biotechnology or for the classification of polymer dispersions.

Table 1
Characterisation of the DYNO filter

Principle	Continuous, dynamic cross flow filtration
Separation duties	Liquid purification, thickening, washing, sieve filtration
Applications	
Suspensions	Newtonian suspensions up to viscous, intrinsic viscous or thixotrope suspensions
Particle diameter	0.01–200 μm
Temperature	Up to 200°C
Performance range	
Filtration pressure	Up to 6 bar
Filtrate throughput	>150 l/m^2 h
End concentration	Up to 65 volume %
Filter media	Polymer/ceramic/metal membranes with pore sizes of 0.01–1.0 μm
Sieve media	Multilayer wire cloths down to 25 μm

In comparison to the classical cross flow filtration, the required results are attained already after one process cycle without repeated recirculation. Therefore, big pumps, recirculation vessels etc. can be saved. The hermetically sealed system, which is pressure tight up to 6 bar, makes it possible to filter even suspensions with odorous emissions or suspensions with toxic ingredients. With permitted working temperatures up to 200°C, the DYNO filter is suitable for products, which are dissolved at high temperatures and shall be discharged with the filtrate. A crystallisation of dissolved substances is securely avoided.

5.1. Thickening and clarifying with the DYNO filter

The principle of the dynamic cross flow filtration and the serial arrangement of the filtration chambers enable a high concentration of the suspensions in one passage through the DYNO filter. At the conventional cross-flow filtration, e.g. with tubular modules, end-concentrations of some 10–20 volume % are possible. With the DYNO filter, however, concentrations up to 65 volume % are achieved. In most cases, the filtrate flow rates exceed 150 l/m^2 h, while with the conventional cross flow filtration, the throughputs lie in the range of 10–150 l/m^2 h. A comparison of the typical performance ranges of both processes is shown in Fig. 2.

The DYNO filter offers interesting possibilities particularly for separation tasks where a highly thickened but still flowable concentrate is required, e.g. if the concentrate has to be dried with spray dryers. The dynamic cross-flow filtration is also an ideal process for the treatment of suspensions/dispersions where the inclusion of air in the pores of the concentrate is not tolerated.

In Fig. 5 a typical curve of the filtrate flow in the DYNO filter is shown for a $CaCO_3$ suspension with particles of 60% below 1 μm. Fig. 5 demonstrates the wide range of concentration in which the DYNO filter can be operated. The results are obtained with a pressure of 0.5 bar and with a rotor speed of 1350 rpm, as filter medium a 0.2 μm membrane is used. The maximum flow rate with this setting of apparatus and process parameters is 500 l/m^2 h. With increasing concentration the filtrate flow naturally decreases, but even with very high concentrations of nearly 75 weight % there is a considerable flow rate of some 20 l/m^2 h. The filtrate is absolutely particle-free. Increasing the pressure and the rotor speed would even improve the filtrate throughput.

In Table 2 further performance data with several products are shown demonstrating the high filtrate throughputs and the high concentrating rate. The filtrates obtained with the DYNO filter are crystal-clear. In all examples shown in Table 2 no further treatment of the filtrate is necessary.

Table 2
Performance data of the DYNO filter

Product	Characteristic product/ process features	Feed concentration (w%)	Concentration of retentate (w%)	Filtrate throughput (m^3/m^2 h)
Industrial waste water		0.3	11	0.9
Red mud		30	65	0.3
TiO_2	Abrasive,	34	59	0.4
	high porosity	40	50	1.0
Ultramarine		17	55	0.3
Yellow pigment		4.5	20	0.4
Molybdenum-orange	High intrinsic viscosity	5	50	0.75
Silica acid SiO_2		13	40	0.8
Bentonite	Slimy, highly water absorbent	2.4	6.7	0.10
Borine carbide	Abrasive	21	52	0.15
Glaze for ceramics	Washing out of slimy contents	33	72	0.15
Silicon carbide	Extremely abrasive	26	66	0.1

5.2. Washing of the concentrate

The washing out of dissolved substances and the displacing of the mother liquor are applications, which the DYNO filter solves with excellent results. The serial arrangement of the filter modules and the possibility to feed each filter chamber with wash liquor allows many alternative process designs for washing and extraction in current and counter-current operation.

Before entering the first wash chamber, the suspension is pre-thickened in one or more filter chambers. In the wash chamber the wash liquor is fed through an opening in the stator disc and thoroughly mixed with the suspension by the rotor. This provides an intensive contact between the wash liquor and the solid particles. The diluted suspension is then thickened again and washed in further wash stages. Since every stator disc has an opening for wash liquor, it is possible to equip the DYNO filter with wash stages in any required number and in any position of the apparatus. Having passed the last wash chamber, the suspension is thickened again and discharged as intensively and evenly washed out concentrate.

Problematical phenomenon like, e.g. a fingering do not appear in the DYNO filter. Therefore, the DYNO filter enables an effective washing with low wash liquor consumption, even of such suspensions which can not be washed on cake forming filters like drum filters or filter presses due to channels in the filter cake through which the wash liquor passes unimpeded and without any wash effect.

In Fig. 6 the wash curve of a pigment washing is shown. With the DYNO filter the salt content of the pigment-expressed as conductivity in μS is reduced in six wash chambers by a factor of 100. Compared to the two-stage washing on two drum filters the DYNO filter provides an absolute particle-free filtrate and a higher solid concentration with considerably less filter area.

The DYNO filter can also be operated as rewash process in combination with running filters on which only poor wash results are achieved.

5.3. Sieve filtration

At sieve filtration the DYNO filter is used for a continuous separation of coarse particles from the suspension. In this case the fine fraction and the mother liquor pass the sieve medium and are removed via the filtrate channels in the stator discs. The substantially smaller coarse fraction is hold back by the sieve, concentrated in the chambers and discharged via the discharge valve as highly concentrated residual suspension.

The DYNO filter can be applied successfully for demanding sieving tasks with high concentrated suspensions and fine sieve cuts, e.g. the sieving of high concentrated mineral suspensions like kaolin or the sieving of a high viscous polymer dispersion with a sieve cut at 25 μm.

6. Apparatus data

The DYNO filter is available with different module diameters and different numbers of modules. The filter area

Table 3
Apparatus data of the DYNO filter

Filter area (m^2)	No. of filter modules	Module diameter (mm)	Dimensions $L \times W \times H$ (mm)	Weight (kg)	Drive (kW)
0.13	55	137	1400/600/1400	300	3
1	8	310	1800/1100/1800	700	7.5–15
4	16	430	2100/2100/1700	2200	18.5–45
12	12	850	3000/2200/1900	5000	45–11

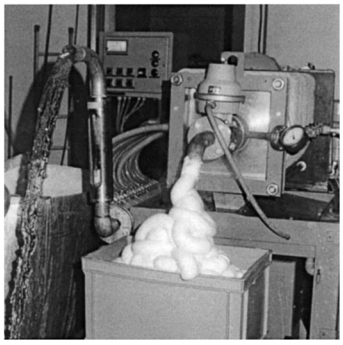

Fig. 4. The concentrate from the DYNO filter is often dry as a firm filter cake but still flowable, the filtrate is crystal-clear.

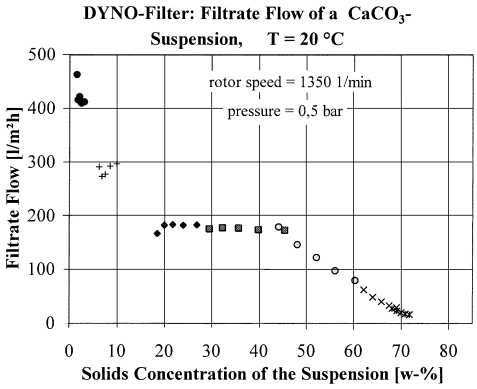

Fig. 5. Filtrate flow versus solids concentration of a $CaCO_3$ suspension.

varies from 0.13 up to 12 m^2. The most important apparatus data are listed in Table 3.

7. Conclusions

The dynamic cross flow filtration with the DYNO filter is a separation process which offers excellent process solutions

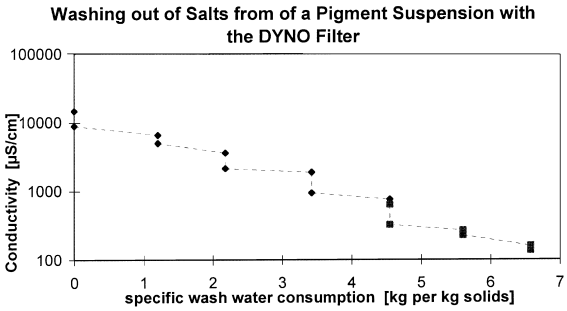

Fig. 6. Washing out of salts from a pigment with the DYNO filter (conductivity of the suspension versus wash water consumption).

especially for suspensions which are difficult to separate or if demanding separation targets are required. Suspensions with Newtonian flow behaviour as well as suspensions with viscous, intrinsic viscous or thixotrope characteristics can be thickened, washed, clarified or classified with high filtrate flow rates. With the DYNO filter suspensions can be highly concentrated up to the flow limit in only one filtration cycle. In most cases the concentrate is as dry as a firm filter cake and the filtrate is crystal-clear (Fig. 4). Sieve filtration tasks for separating of coarse grain are performed with high concentration factors of up to 1000.

Contrary to the classical cross flow filtration the separation task is performed with two to ten times higher throughput rates while simultaneously higher concentrations in the retentate are achieved without a multi-repeated circulation of the suspension. Compared to other separation processes, the dynamic cross flow filtration with the DYNO filter needs no consumable filter aids like precoat filters and provides better filtrate qualities like, e.g. centrifugal separators or candle filters.