INVESTIGATIONS ON BACK FLUSH AND PULSATORIC FLOW CLEANING OF POLYMER WOVEN FILTER MEDIA

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ABSTRACT

A safe and efficient cleaning of processing equipment is an important demand in the pharmaceutical, biotechnology and food industry. This ensures a high product quality by avoiding cross contamination. However, cleaning leads to down times of the production line and hence to higher costs. To reduce these costs it is necessary to realize a faster and more efficient cleaning. This can be achieved by a construction of the plant according to hygienic design criteria. In the field of pipe components and tanks there are different test methods (EHEDG cleaning test, Qualified Hygienic Design Test) available to test the cleaning efficiency. Excluded from this, however, are filter media. Therefore it is interesting to investigate the physical principals of filter media cleaning. This paper compares two cleaning methods for filter media: the back flush cleaning process and the pulsatoric flow cleaning.

KEYWORDS

Filtration, cleanability of filter media, back flush, pulsatoric flow

1 Introduction

In filtration processes the cleanability of filter media plays an important role. It is often a great challenge for manufacturers and operators of filtration equipment. The main problem which occurs by starting a new batch is cross contamination. Because of this filter media are often replaced with new ones after a filtration process.

If a cleaning problem occurs, often the concentration of the cleaning solution, the cleaning process duration and the temperature are increased severely. But this often causes more problems. Higher temperatures and higher concentrated cleaning solution can destruct the filter surface or the gaskets of the filter machine.

The impurity which remains on the filter media after a filtration process is often a compound of soluble and not soluble particulate residuals. In this work we only focus on a particulate contamination.

Two cleaning methods for filter media are presented and contrasted with each other. In a first step the results of a backflush cleaning process are demonstrated. Here the influence of time and of temperature of the cleaning solution is investigated.
In a second step the results of a pulsation flow cleaning are presented. In cross flow filtration this method is often used to reduce membrane fouling [1], [2], [3].
In a last step the results of both methods are compared to each other. The aim is to increase the cleaning grade of the filter media with the help of the pulsatoric cleaning method.

2 Materials and Methods

2.1 Filtermedia

For the investigations we used three different filter media. In table Table 2-1 the filter media and their characteristics are demonstrated. The main experiments were done with filter media with pharmaceutical grade (17-2005-Sk-012).

Table 2-1: Investigated filter media and their characteristics

Filter name	*material*	*porosity*	*Fineness in µm*	*Filter texture*	*finish*
17-2005-Sk-012	PEEK	0,48	12	PRD	Super calendered
07-90-Sk-012	PET	0,61	12	PRD	Super calendared
07-76-Sk-022	PET	0,61	22	PRD	Super calendared

2.2 Particles

The particles used as contamination are shown in Figure 2-1. They are monodisperse fluorescent melamine resin particles with a range of 10 microns. They are insoluble in water, bases and acids and they have a high thermal resistance (till 300℃). So the particles are capable for temperature experiments, with a view to investigate the influence of temperature on the cleanability of the filter media.

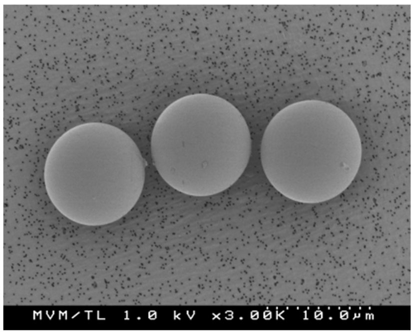

Figure 2-1: Particles used as contamination

2.3 Through streaming plant

At the Institute of Mechanical Process Engineering at the KIT a through streaming plant for cleaning experiments was developed. In Figure 2-2 the scheme of the plant is shown in detail. It consists of two pressure vessels and a filter holder, in which the polymer filter media is fixed closely. The vessels serve as a reservoir for the cleaning solution (e.g. water, acid or base). For the experiments only demineralized water was used. During the process the mass flow, the temperature of the cleaning solution and the pressure of the vessels can be controlled. For the experiments a mass flow of 30 g/s respectively 2 g/s and cleaning times of 10, 30, 60, 150, 300 and 600 seconds are realized.

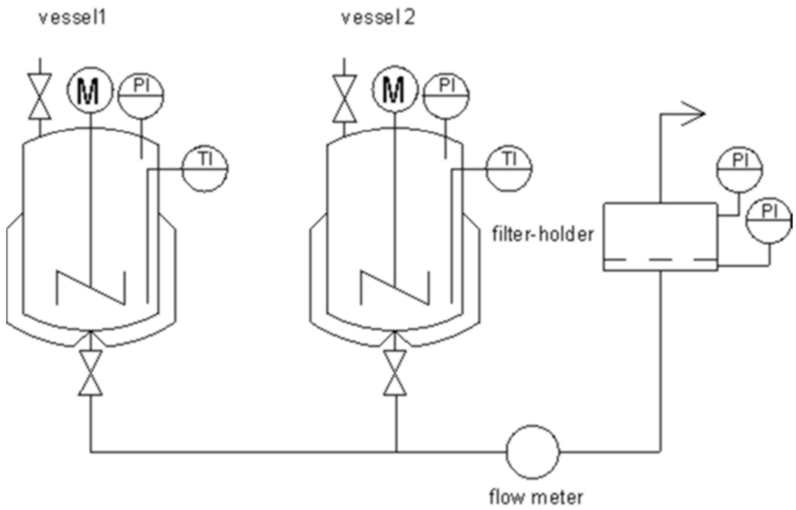

Figure 2-2: Through streaming plant

2.4 Pulsation flow plant

Also a pulsation flow plant was developed at the Institute of Mechanical Process Engineering to investigate the influence of the pulsatoric flow on the cleaning behavior. In Figure 2-3 the plant is schematically shown. It consists of three pressure vessels and a fast switching magnetic valve generating the flow pulses. The magnetic valve is connected to a cone placed 10 mm in front of the filter media. The filter media is fixed between two cylinders made of Plexiglas, to observe the cleaning process. During the pulsation process a continuous flow of cleaning flows through the filter media. The mass flow was set to 2 g/s. Avoiding the backflow of the cleaning solution, a relapse valve is added in front of the magnetic valve. Vessel 1 and vessel 2 serve as a reservoir for the cleaning solution, which is pumped by pressure through the filter media. The cleaning solution in vessel 3 can be pumped also by pressure through the magnetic valve through the cone and then through the filter media. With the pressure the velocity of the pulse flow can be regulated.

The magnetic valve is controlled by a Siemens Logo System. There the duration of one pulse, the time between two pulses and the number of pulses can be operated. So in this work four parameters are verified for the investigations.

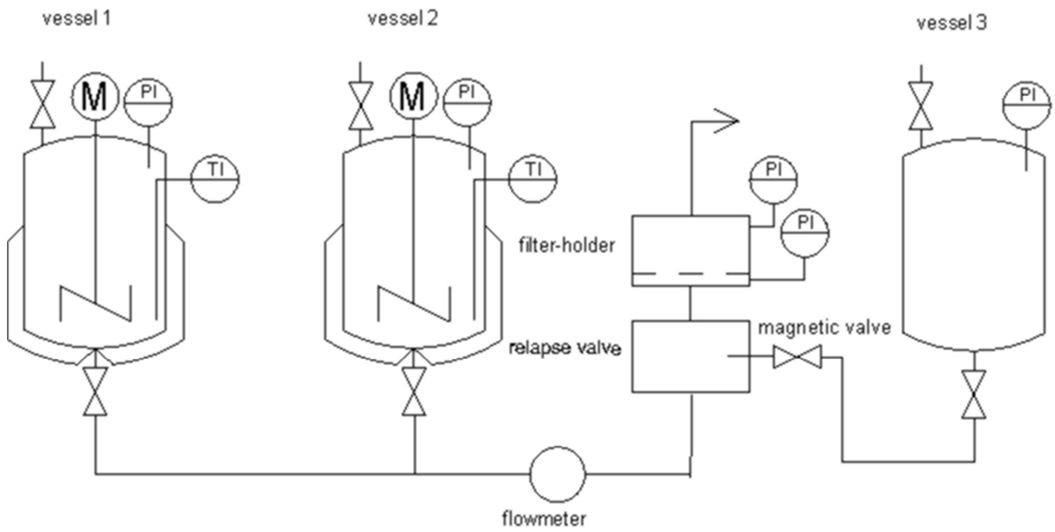

Figure 2-3: Pulsation flow plant

2.5 Contamination of the filter media

Before starting the cleaning experiments the filter media must be contaminated reproducible. This is realized with a contamination unit, where the filter media is clamped closely. The operating mode of the contamination unit relates to the one of a pressure nutsche. With its aid a thin filter cake can be formed on the filter media. But this work focuses on the cleanability of filter media therefore it is interesting to clean the single particles remained on the filter media after the filter cake discharge. So in this work the contamination was done with a high diluted particle suspension, in order to bring single particles on the filter media. Pretests showed that the remained particles after cake discharge, locate in a similar way on the filter media like the particles brought on the filter media with the help of the contamination unit.

After the contamination and before the cleaning process the number of particles on the contaminated filter media is determined. This is carried out with the help of a fluorescent microscope and the software Photoshop(R), where the pictures of the filter media can be optimized and the particles then can be counted with the software Image J. After the cleaning process pictures of the same positions are taken and the particles are counted with the same method. So it is possible to accumulate the retention of the particles on the filter media after the cleaning process. In equation 2-1 the retention of particles is demonstrated:

$$R = \frac{number\ of\ particles\ on\ the\ filtermedia\ after\ the\ cleaning\ process}{number\ of\ particles\ on\ the\ filter\ media\ before\ the\ cleaning\ process} \quad \textbf{2-1}$$

3 Results and discussion

3.1 Influence of the back flush cleaning process on the cleanability of filter media

The following experiments were done in the through streaming plant described in chapter 2.3. The experiments focus on the influence of the temperature of the cleaning solution and on the influence of the process time on the cleanability.

3.1.1 Influence of the time on the cleaning process of filter media

In the following figure pictures of the filter media after different cleaning times are shown. The flow velocity was constant at 0,004 m/s. At the beginning (cleaning time t=0) a cake was formed out of the fluorescent particles. For every experiment the filter was contaminated again and a picture was taken at certain times. The pictures were taken after 0, 10, 60 and 300 s (Figure 3-1).

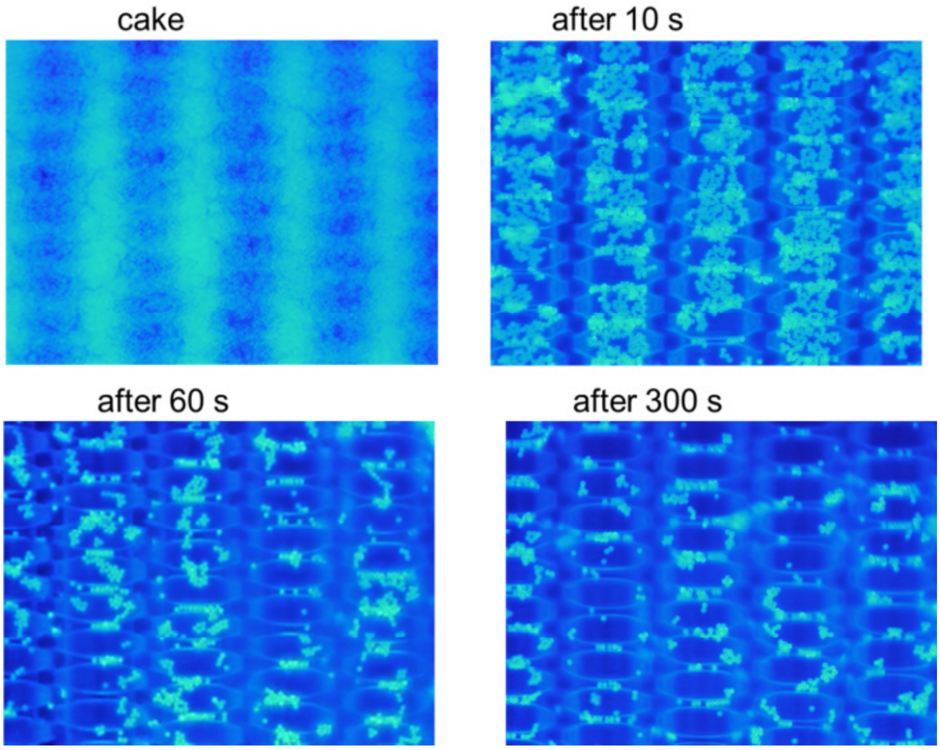

Figure 3-1: Filter 07-90-sk-12 after different cleaning times

After 10 s the meshes are free of particles, but most of the impurity is located on the fibres and between two fibres adjoined each other. It is conspicuous (see pictures after 60 and 300 s) that the critical cleaning points of a filter media are mainly between two adjoined fibres.

3.1.2 Influence of the temperature of the cleaning fluid

In the following figure the influence of the temperature of the cleaning solution is shown. The cleaning solution was in this case demineralized water and the flow velocity is 0.06 m/s. It is evident that the higher the temperature the better is the cleaning result. This can be noticed between the temperatures 20 and 80℃. But after a cleaning time of 600 s no difference in the retention can be seen.

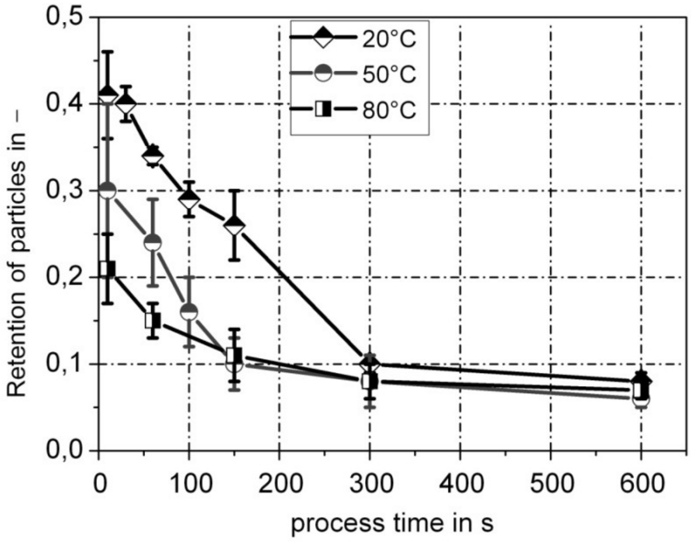

Figure 3-2: Dependence of the temperature of the cleaning solution on the cleanability of the filter media 07-90-sk-12

On the first view many explanations for this fact come to mind. Temperature influence of the van der Waals force, the influence of the viscosity and temperature influence of the electrostatic force can for example cause this result.

The van der Waals force is referred to Lifshitz dependent on temperature. In equation 3-1 this dependence is shown. Here A is the Hamaker constant, ε the dielectric constant ν_e is the absorption frequency of the cleaning solution, k the Boltzmann constant and n the refractive indices of the materials.

$$\boldsymbol{A \approx \frac{3}{4} kT \left(\frac{\varepsilon_1-\varepsilon_3}{\varepsilon_1+\varepsilon_3}\right)\left(\frac{\varepsilon_2-\varepsilon_3}{\varepsilon_2+\varepsilon_3}\right) + \frac{3h\nu_e}{8\sqrt{2}} \frac{(n_1^2-n_3^2)(n_2^2-n_3^2)}{\sqrt{(n_1^2+n_3^2)}\sqrt{(n_2^2+n_3^2)}\left[\sqrt{(n_1^2+n_3^2)}+\sqrt{(n_2^2+n_3^2)}\right]}} \qquad \textbf{3-1}$$

After Lifshitz the Hamaker constant and consequently the van der Waals force increases with increasing the temperature. But our results show the opposite. So the temperature can´t be the main influence of the better cleaning results.

Another explanation could be the viscosity of the cleaning solution. The higher the temperature the smaller is the viscosity. The wall shear stress which a particle is affected to is known and described in the following equation:

$$\boldsymbol{\tau_w = \eta \cdot \left(\frac{\partial u}{\partial y}\right)} \qquad \textbf{3-2}$$

Here $\boldsymbol{\tau_w}$ is the wall shear stress $\boldsymbol{\eta}$ the viscosity and $\boldsymbol{\left(\frac{\partial u}{\partial y}\right)}$ the velocity gradient.

The higher the viscosity of the cleaning solution is the higher is the wall shear stress on the particles. So the cleaning result must be better at higher viscosities and consequently at lower temperatures. But the results in Figure 3-2 show the opposite. So the influence of the viscosity can´t be the main influence for the results.

The only force which can be the main influence is the electrostatic force. In equation 3-3 the correlation of the electrostatic force of different parameters is shown.

$$\boldsymbol{E_{rep} = 32 \cdot \pi \cdot d \cdot k \cdot T \cdot n \cdot \delta^2 \cdot e^{-\frac{a+a_0}{\delta}} \tanh\left(\frac{z_i \cdot e \cdot \zeta_1}{k \cdot T}\right) \cdot \tanh\left(\frac{z_i \cdot e \cdot \zeta_2}{k \cdot T}\right)} \qquad \textbf{3-3}$$

Here is A the contact area, T the absolute temperature, ζ the zeta potential of the filter media or the particles, δ the thickness of the diffusive layer, a_0 the adhesion distance, $a_0 + a$ the distance between the two contact partners, z_i the ionic valence, k the Boltzmann constant, e the electron number. d the particle diameter and n the number of ions per volume in the medium The electrostatic force is proportional to the temperature. With an increasing temperature the electrostatic repulsion gets higher. In literature also a temperature dependence of the zeta potential was noticed [4].

3.2 Influence of the pulsatoric flow on the cleanability of filter media

The following experiments were done with the pulsatoric flow cleaning plant described in chapter 2.4. The investigations focus on the influence of pulse duration, pulse velocity and the pulse frequency.

3.2.1 Variation of the pulse duration and pulse velocity

In Figure 3-3 the dependence of the pulse duration and pulse strength is shown. Plotted is here the retention of particles against the pulse velocity. The different symbols of the measured points describe different pulse durations. These experiments were done with one pulse and a continuous flow of 0,004 m/s. The process time was at 25 s.

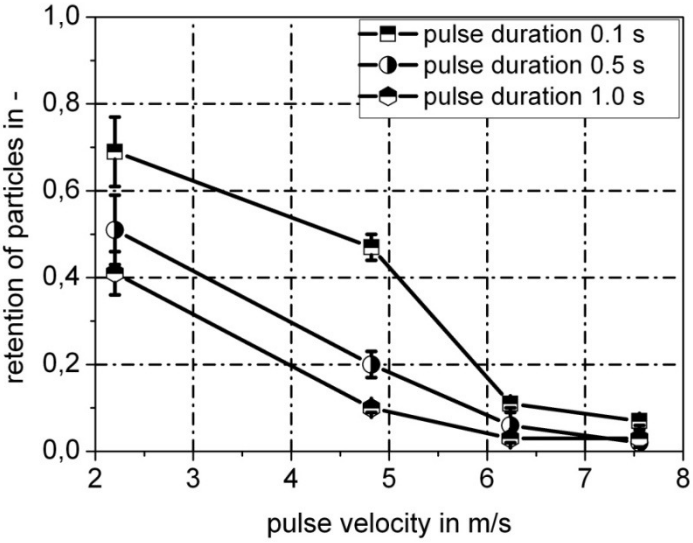

Figure 3-3: Influence of the pulse duration and the pulse velocity

It is evident, that the higher the pulse velocity the better the cleaning result and the higher the pulse duration the better is the cleaning result Some more experiments for the investigation of the pulsation flow were investigated like the frequency of pulses and the process time. They will be presented in the oral presentation. In the following the experiments of the continuous back flush cleaning and the pulsatoric backflush cleaning are compared to each other (Figure 3-4). Plotted is the retention of particles on the filter media against the volume of the cleaning solution. The different squared symbols demonstrate the pulsatoric process at different pulsation duration. The scattering of the measuring points is caused by different pulse velocities. The round symbols picture the continuous back flush process. It is evident, that the pulsatoric process is much better than the continuous process. The pulsatoric process provides in addition to better cleaning results (only 3 % of particles remain after 25 s at a pulse velocity of 7.55 m/s on the filter media and at the back flush process 35 % remain on the filter media) also a volume reduction of the cleaning solution. Maximal 150 ml were consumed at a pulse duration of 0.1 s and a pulse velocity of 7.55 m/s. For the continuous process 580 ml (after 300 s process time) are consumed achieving a retention of 38 %.

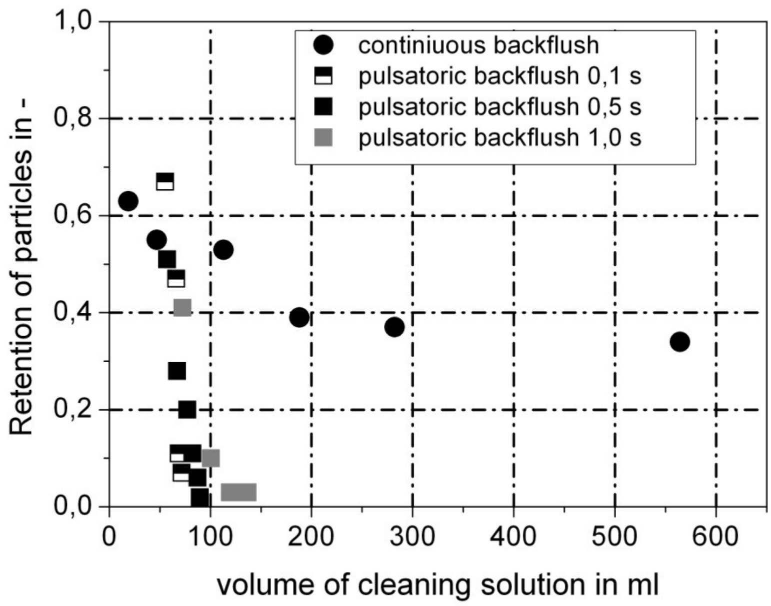

Figure 3-4: Comparison of continuous backflush and pulsatoric backflush at different pulse durations

4 Conclusion

It is evident that the cleaning process time and the cleaning solution temperature have a significant influence on the cleaning behaviour for particulate contaminations.

The results also show that the pulsatoric cleaning method attains a better cleaning rate for the filter media than the continuous back flush method. A cleaning rate of 97 % is achieved at the pulsatoric cleaning method whereas with the back flush method only 62 % is preserved. So the pulsatoric method seems to be a better alternative for filter media cleaning.

5 Literature

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