Requirements to Eliminate Gel Particles in Different Processes

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Abstract

Gel particles can cause more serious problems in the process industry. Insoluble particles can be present wherever solids are dissolved in a solvent, resulting in product quality degradation or equipment malfunction. The consistency of gel particles can vary considerably, ranging from a rubbery consistency to particles which are still in the fluid state and merely have a higher viscosity than the surrounding fluid. Gel particles can have different properties, and that places significant demands on the filtration system.

Depth filtration:
Compared to screens, the material used for depth filtration is much more effective at removing soft particles. The reason is that a gel, which fits through a pore in the material, is captured in a deeper layer. In order to exploit this effect, Lenzing Technik uses a multi-layer, stainless steel, non-woven fiber fabric on its ViscoFil® and AKF series for backwash depth filtration applications.

Differential pressure:
For gel particles the differential pressure must be kept low during filtration to prevent the particles from being forced through the pores in the filter material. Lenzing Technik uses extremely fine stainless steel fibers (as small as 2 μm) to produce a highly porous filter material. This feature, plus the absence of any pleating, makes the filtration systems suitable for very high viscosity media at very low differential pressures.

Texture of the filter materials:
Soft filter material, for example filter felt, has one major disadvantage. If the flow rate varies or particle loading increases, the differential pressure and the shape of the pores in the filter also change. A particle, particularly a gel, obviously exerts a force on the surrounding material (e.g. the felt fibers) when a pore is blocked, eventually causing the particle to slip through. On the Lenzing filters, the problem was solved by mounting a special tensioning frame which holds the filter material over a perforated support tube and the filter material retains its structure.

Gel particle residence time in the filter:
Lenzing filters have a patented backwash feature which automatically removes gel particles from the metal fiber fabric. Backwashing can take place at regular 30 second intervals if necessary. This ensures that there is not enough time for the gel particles to be pressed through the pores.

Keywords: automatic filters, filter media for liquids; meshes, metal, porous filter media, self cleaning filters, stainless steel filters
Introduction

What is a Gel Particle
On Wikipedia you will find the following definition for the term gel:
“Gel (from the Latin gelu ›frost, cold, ice‹ or gelatus ›frozen, rigid‹)”
This definition of the term is misleading in two ways. First of all gel particles are not, as one might deduce from the definition, crystal-like congealed liquids which would in turn be hard and thus easy to filter. They occur more often in consistencies which are at best similar to gum sweets (Gummibärchen) and are in worst case still liquid and only have a higher viscosity than the fluid in which they occur.
Moreover, in most cases when producing man-made fibers this is not a “congealing process” from one fluid but more the insufficient dissolution process of a solid in a fluid or an insufficient melting procedure.

How Gel Particles Arise
Two mechanisms are known in the production processes of man-made fibers or films of solvents for the creation of gel particles.

Insufficient Dissolution of Solid
In most of the processes based on solvents for the production of man-made fibers or films, a polymer (cellulose acetate, polyacrylonitrile, polyimide, polyvinyl alcohol, polycarbonate, polyurethane, or pulp of wood or cotton linters) is dissolved in a solvent. A dissolution process of this kind demands above all time and in most cases additional processing such as stirring, the introduction of heat or shearing forces, an increase in pressure, etc. In some cases, e.g. when using dissolving pulp, it is also necessary to prepare the solid in a chemical way to make it accessible for the solvent. When dissolving a solid the gel phase is always an intermediate step in the transition of the aggregate condition from solid to homogenous liquid.
If the time, stirring energy, temperature or shearing force is not sufficient, the gel particles will stay behind in the liquid. The best way of dealing with this, however, is not filtration. Instead, it is appropriate to work on the process-technological details already mentioned or to simply give the process more time wherever this is possible.

Insufficient Solubility of Solid
In addition to the insufficient dissolution of the solid, the insufficient solubility of this can also be a reason for the creation of gels.
Thus, with cellulose acetates for example, there is always a small share of not sufficiently converted (acetylated) components. These would still be in the form of gel particles after an endlessly long dissolution time and must therefore be removed in another way.
Likewise with polymer fibers, for example of polyacrylonitrile in most cases gel particles are formed due to the inhomogeneties in the raw material.
In addition when introducing the powder to the solvent, lumps can result in gels which cannot then be dissolved.
For the viscose process the formation of gel from incompletely saponified resin particles is to be mentioned in addition to the insufficient conversion (sulphidation) of the raw material (similar to the example of cellulose acetate).

Problem of Gels in the Different Processes

Optical Films
Optical films are mostly produced in the dry cast process of cellulose acetate which was dissolved in methylene chloride prior to this.
The films are traditionally used in the photography field and in the last few years to an increasing extent in the production of TFT screens in the electronic industry, from mobile phones to computer screens through to large LCD TVs.
The problem here lies in the fact that gels have a different refractive index than the rest of the film due to their composition. Thus these become visible in the final application on the lit-up display.

Figure 1. Example for a LCD screen.
Man-Made Fibers
In the spinning process of man-made fibers the polymer solution is pressed through a very fine nozzle and on the nozzle outlet side either precipitated in a chemical bath by means of coagulation or the solvent evaporates as a result of introducing temperature and the polymer is dried. In both cases the polymer remains in the form of a fiber. Problem: the gels here lead to blocking in the spinning station as well as to a reduction in the fiber tenacity through to fiber breakage particularly since the fibers are then mostly stretched via rolls following spinning which further reduces the fiber cross section.

Carbon Fibers
Carbon fibers are used to reinforce plastics and are gaining in popularity since these plastics can be made with the strength of steel but with only a fraction of the weight. The problem with carbon fibers is that as a result of the process of „carbonization“ (similar to the production of charcoal) of a conventional man-made fiber (viscose or polyacrylonitrile) a part of the polymer is carbonized and the fiber is therefore tapered further in its cross section. This already leads to considerable quality impairments with gel particles of a size of only 5 μm (microns).

Factors Influencing the Filtration of Gels

Depth Effect
It does not come as a surprise that a filter material with a depth effect is much better suited to filtering soft particles than a sieve. This is quite simply because a gel which penetrates a pore has much more chance of possibly being retained in pores lying further back.

The Lenzing filter:
Here Lenzing Technik uses a special multi-layer high-grade steel fiber fleece with a depth effect which has been specially adapted to the backwash filtration of spinning solutions (see Figure 2).

Figure 2. Photo of filter material used for the Lenzing filter.

Influence of Differential Pressure
Moreover it is not hard to understand that with a particle which is completely hard and a completely hard pore of the filter material, the differential pressure impacting on the particle in the filter material during filtration can become endlessly high without this having a negative influence on the filtrate quality. The softer the gel particle, the lower the differential pressure has to be during filtration so that this cannot be pressed through the pore in the filter material.

The Lenzing filter:
A very high porosity of the filter material can be obtained by using extremely fine (down to 2 μm) high-grade stainless steel fibers. In this way and due to the lack of any pleating the filters are operated even with the highest

Figure 3. Comparison – filtration of a crystal and a gel.
possible viscosities with differential pressures of between 1 and 3 bar. Only in a few rare cases differential pressure can rise to approx. 5 bar after longer periods of operation of several months.

**Influence of the Texture (Deformability) of the Filter Material**

With regard to the filtration of spinning solutions for the production of man-made fibers, in the past filter felts were mainly used, made of cotton, PP, PES or nylon fiber. These filter media have a relatively soft texture and can thus be easily deformed.

The disadvantage of this kind of filter media is, that when the conditions vary (change in throughput, increase in particle load raises the differential pressure etc.) the shape of the pores changes. The filter medium is compressed to a greater or lesser extent. The pores close or open more.

As a result of these changes forces are exerted on the gel particle which can deform it and in the most unfavorable case “extrude” it through the filter medium.

In addition of course a particle and in particular a gel, when it blocks a pore, exerts a force on the surrounding material (e.g. the fiber of the felt) and tries to extend the pore which ultimately again leads to the extrusion of the particle (see Figure 4).

**The Lenzing Filter**

With the ViscoFil® and AKF filters, the filter material is mounted on to the perforated support tube by means of a special mounting basket (= “Fixing cage”) (see Figure 5).

This mounting is performed by means of a precisely defined screw forces so that the load exerted on the filter material by the fixing cage equals a differential pressure of 6 bar. If one now looks at the other side of the filter material with due consideration to the laws of the balance of forces then it becomes clear that the perforated drum (perforated support tube) exerts the same force on the filter material in the opposite direction. Therefore the filter material is balanced in terms of the forces.

If one now starts with filtration from the inside outwards, the differential pressure via the filtermaterial rises. Let us assume that this equals 2 bar. To obtain the balance of forces, the differential pressure disburdens the perforated drum due to the direction of filtration. This means that the new balance of forces is now: from the one side 4 bar from the perforated cover plus 2 bar from the filtration differential pressure. From the opposite direction the same 6 bar of the mounting basket. Therefore, up until the value of the pre-tension pressure of the mounting basket (6 bar) the filter material does not change its structure, thickness and thus pore size, even if the differential pressures change. Together with the natural rigidity of a sintered metallic fiber fleece this results in an extremely rigid structure.

**Influence of the Retention Time of Gels in the Filter**

One realization which became obvious in recent reference applications is the influence of the retention time of the particle in the pore on the filtration quality of the gels.
Figure 6 shows a typical gel particle in the form of a hard boiled and peeled egg. It should be remembered that the boiled egg represents a comparably hard gel particle. The effect depicted will be much faster with very soft gels in spinning solutions.

Test course: A hard boiled egg is placed at the opening of a bottle too narrow to allow direct passage. The bottle is then placed in a slight vacuum i.e. the differential pressure between the gel inlet side and gel outlet side is simulated. One should now observe the time. The differential pressure does not change very much. However, the egg begins to deform bit by bit, it becomes longer, tapered and then finally it emerges again in the bottle (“on the filtrate side”).

**Conclusions**

Within \( t = 3 \frac{1}{2} \) minutes a gel particle with the viscosity of a peeled egg and a diameter of \( d = 51 \) mm penetrates an opening with a diameter of \( D = 33 \) mm of a pore, if one applies a constant differential pressure of \( \Delta p = 20,000 \) Pascal.

One can now apply this conclusion to any viscous gel, high differential pressure, small diameter of the gel particle and even smaller pore.

The fact always remains that gels can penetrate any filter material after a certain time.

**The Lenzing Filter**

The filters in the AKF and ViscoFil® series have a patented backwash mechanism in which the metallic fiber fleeces are freed of gel particles and naturally also of solids in a fully automatic way. This can, if necessary, be done up to every 30 seconds. In this way the gel particle simply does not have enough time to be extruded through the pore. Filtration remains intact during the backwash which is only taking place partially. (At a small portion of the filter area at a given time)

Some more recent examples, in particular with regard to the filtration of optical film, an extremely demanding filtration task, have shown that the film quality had clearly improved only as a result of increasing the backwash frequency and this was the case although no increase in the differential pressure had indicated a filter material blockage.

Suitable processes for recycling backwash solution (“Reject”) are available for a wide range of different fluids.