Polymerisation / Raw Material Manufacture
Processing Technical Requirements on Filtration Systems

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1. Introduction

In the manufacture of raw materials or polymerisation processes the use of filtration systems is normally a common standard in order to ensure a constant melt quality. Examples of impurities that need to be filtered out can be burned particles and/or solid agglomerates of polymer.

A typical process configuration for the manufacture or polymerisation of polymers is as shown below:

![Diagram of polymerisation process]

In the case of PET, the final reactor is referred to as a “Finisher”, in nylon manufacture a “tube” but the basic arrangement is – seen from the viewpoint of the filtration system – basically similar.

From numerous, diverse applications in polymerisation processes, Gneuss was able to work out a “Wish List” for the characteristics which a Filtration System for the optimum performance in the Polymerisation Process should have.

2. Polymer Manufacturer’s “Wish List” for a Melt Filtration System

a) Short Residence Time

The Filtration System should operate with a minimal residence time. Even today, many processors either filter coarser than they really need (so that the Filter is kept as small as possible to minimise the residence time) or in many cases even do not filter at all in order to avoid the residence time problems of conventional filters. Particularly critical cases are PA (nylon) PET and PBT. The higher the melt viscosity, the more critical this problem becomes so that even on materials e.g. for technical yarns, there is no filtration even though many tests have shown that filtration finenesses of finer than 20 microns can achieve major improvements in the polymer quality and the subsequent spin pack life.
b) Fast Reaction Time to Contamination from the Process

Whereas polymer filtration often means the removal of foreign particles from the melt, filtration in Polymerisation processes refers to the removal of unwanted particles which originate from the material itself: residual additives, the inevitable burnt particles from small dead areas in the melt flow path, etc..

The unwanted particles are never distributed uniformly in the polymer. Typical problems are for example high contamination loads caused when a batch of low quality raw input materials is used or if there are some problems in controlling the process.

When processing “accidents” like this occur, it is important to be able to exchange the active area quickly in order to maintain production of the material at an acceptable quality. If the Filtration System can not exchange the area sufficiently fast, the processor will have no alternative than to remove the filter elements completely and produce out of specification “off grade” which, will have to be sold off at a low price with practically no margin, until the poor quality batch of input raw material has been used up or until the process control problem has been solved.

Clearly, if a Filtration System can “save” the production under such circumstances, there is a major cost advantage for the processor.

c) No Out of Specification Material During Filter Changes

Although apparently a paradox, some screenchanger systems (double piston screenchanger) available on the market actually create their own contamination. The problem is that the layer of polymer on the exposed external section of the piston is stagnant and in contact with oxygen. This material degrades and becomes a hard, burnt, black layer. When the piston is moved, the oscillating movement leads to this burnt layer being moved backwards and forwards through the polymer melt. Inevitably, some burnt particles will break off and will find their way into the final product.

Additionally, as this process is completely manual, additional personnel is needed during this time.

In order to ensure that none of this suspect material finds its way to the end user, the material made during, and for roughly 15 to 20 minutes after screen changes, is collected separately as “off grade” and sold off at a low or with no margin. Although this is common practice, some raw material manufacturers do not divert the material to “off grade” with the consequent risk to their product quality and their reputation as a raw material manufacturer.

Clearly, a Filtration System, which never introduces contamination into the polymer and with which it is not necessary to manually divert the material to “off grade” during and immediately after screen changes, can make a big difference to a raw material manufacturer’s profit margin.

d) Pressure Stable Operation

With conventional filters, the pressure differential will increase until it reaches the maximum permissible. Then, a filter change is carried out (manually). This saw tooth pressure profile over time may or may not cause quality variations in the final product due to an increase in shear. If however, the conventional filter is of the kind (double piston) whereby the area is reduced during a filter change, then the pressure differential will increase dramatically during this time. This means that a) the full throughput rate is flowing across the already contaminated screenpack(s) possibly damaging them and b) if the downstream process has an underwater pelletiser, the discharge pressure of the melt pump at the base of the reactor may not have sufficient reserves so that the throughput rate must be temporarily manually reduced.
If the reactor discharge pump is slowed down, the level in the reactor will back up. This is usually associated with a decrease in the product quality: contamination is increased and the residence time of the material in the reactor is increased.

**e) High Level of Automation and Safety**

Modern high performance polymerisation lines are designed with a high level of automation. The concept of manually having to initiate filter or screen changes, manually reduce the discharge pump speed and/or manually diverting the material to “off grade” does not fit in well with the concept of a heavily automated production process, which is designed to avoid the opportunities for operating personnel to make mistakes. The replacement of the filter elements should be possible without risking injury or accidents.

**f) Reliability**

It is not enough to simply take a system which works with a fair level of reliability on an extrusion line and scale it up for a polymerisation process. Where practically 100% availability is required, the whole system concept must be designed around this requirement and the performance of the unit must be monitored constantly to prevent any potential problems becoming actual problems.

### 3. Gneuss Rotary Filtration System SFXmagnus and RSFgenius as an answer to the Polymer Manufacturer’s “Wish List”

As an answer to the described wish list of the customers Gneuss developed the rotary filtration systems SFXmagnus and RSFgenius. Both systems are characterised by a rotary disc which is enclosed between two blocks. The disc is completely sealed from contact with the environment. A sealed cover is provided for easy access to replace the screen packs. The melt flow channel design avoids dead area and keeps the residence time to an absolute minimum. One of Gneuss’ specialities is the design of these systems in such a way that they are completely integrated with the customer’s equipment (see below).

The Rotary Disc carries the wire mesh screen packs as filter elements in a ring pattern. The disc is rotated by a stepwise movement, controlled by time and pressure. In this way, the active area remains constant and the melt pressure can be maintained either constant +/-2 bar (RSFgenius) or within a narrow pressure range (SFXmagnus).
In certain cases, an extremely large active area is necessary due to the combination of melt viscosity, filtration fineness and throughput rate. For such cases, the SFX*magnus*X2 and RSF*genius*X2 offer all the benefits of the Rotary Filtration Systems coupled with an extremely large active area of up to 8,200 cm² with a total area of 2,2 m².
The main characteristics of the Rotary Filtration Systems RSF\textit{genius}, SFX\textit{magnus} and SFX\textit{magnus x2} can be summarized as follows.

\textbf{a) Optimised rheology}

The Rotary Filtration Systems RSF\textit{genius} and SFX\textit{magnus} are designed to ensure the optimum melt flow. The flow is never disturbed by diverting the polymer, neither is the flow stopped in some areas during screen changes.

Further, the rotary disc is completely enclosed and sealed airtight. Therefore, except for the short time when the cover is opened for access to change the screen packs (which is not long enough for the material’s properties to suffer), the whole assembly is completely sealed.

Therefore, there are no areas where material can degrade due to being exposed to temperature and oxygen for long periods of time. Hence, no burnt particles can break off in the melt channel during a screen change and find their way into the product.

\textbf{b) Fast Reaction Time to Contamination from the Process}

The Gneuss RSF\textit{genius} and SFX\textit{magnus} can exchange area extremely quickly. (If necessary, over 2 m$^2$ per hour). In the case of the RSF\textit{genius}, with automatic self cleaning. Even during process disturbances or when a substandard raw material is being used, it is possible for the polymer manufacturer to produce “1A” grade material which would otherwise need to be sold off as “off grade” or even scrapped.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{Fig_3.PNG}
\caption{SFX\textit{magnus} / RSF\textit{genius} x2 - example of installation}
\end{figure}
c) No Out of Specification Material During Filter Changes

Compared with conventional screen filters and screen changers, the Gneuss Rotary Filtration Systems offer processing technical advantages which have a major effect on the economic efficiency (and even viability) of the lines.

- No “off grade” material during filter or screen changes
- No strand breaks during filter or screen changes
- No colour variations (yellowing of the material) during screen changes

This is in most cases the strongest economic factor in favour of the Rotary Melt Filtration Systems.

| Case example: | An internationally active Asian Polymer Manufacturer of ABS/SAN pellets operated in the past with semi–continuous Screenchangers. With these Screen changers, it was necessary to diver the production during and for approximately 15 to 20 minutes after each screen change to “off grade”. This material was sold off at a low price. The throughput rate of the line is up to 11,000 kg/h. Therefore, at the maximum throughput rate, 2,750 kg of “off grade” material was produced per screen change, which had to be sold off at production cost (no profit). With the double piston screen changer, up to 3 screen changes per day were necessary, so the total amount of “off grade” was up to 8,250 kg per day.

In the meantime, these screen changers have been replaced by Gneuss Rotary Filtration Systems. The “off grade” problem was completely solved.

Although this case refers specifically to ABS, the situation is similar with most polymerisation processes, even in cases where the conventional filter has a longer life than described in this case, the economic advantages of using the Rotary Filtration Systems to avoid “off grade” are normally significant. |

1 With semi – continuous Screen changers those systems are referred to, which permit continuous production during screen changes but cause production variations and/or disturbances during changes. Such systems are for example duplex candle filters, double or multiple piston screen changers, double slide plate screen changers.

d) Pressure Stable Operation

Screen changes within tightly controlled pressure range

| RSFgenius | The RSFgenius is equipped with an automatic self – cleaning system. The screen packs can remain in the unit for up to 300 filtration/cleaning cycles. This typically means that the unit can run unattended for several months (during replacement of the screen packs, there is no effect on the product) and the guaranteed maximum pressure variation caused by the RSFgenius is +/- 2 bar. |
| SFXmagnus | The SFXmagnus screen packs are left in position whilst the disc is rotated for multiple pass filtration. As a dirt cake develops, the pressure differential increases. At a pre-set pressure differential (this is set well below the critical point), the operating personnel removes the screen packs and the cycle starts again. If necessary, the unit can also be operated in pressure constant mode +/- 3 bar. |
e) High Level of Automation and Safety

The RSF genius and SFX magnus both operate automatically, time and pressure – dependently, the controls can be linked to or integrated with the DCS control room. The filter element usage rate can provide a useful quality control indication (the faster the filter area is exchanged, the more heavily contaminated the material). Further, exchange of the filter elements is a simple and safe task which can be carried out by one person without any special equipment and within a few minutes.

f) Reliability

The Rotary Disc Filtration Systems for polymerisation applications are designed around the requirements of such processes where practically 100 % availability is required. The operation of the unit is monitored by two independent systems. The few wearing parts are fitted in modules so that a swift exchange without interruption of the production process is possible. In the unlikely event of adjustments to the mechanical clearances, this can be carried out during running.

4. Additional process control by the use of a Gneuss Online Viscometer

The product viscosity is in many processes one of the key material properties which the raw material manufacturer wishes to monitor.

Thanks to extensive experience in polymer processing, Gneuss has developed an online viscometer which provides real time online viscosity measurements. The material is taken out of the system for measurement and returned to the main flow, so the system does not involve any material loss. The Gneuss system is based on the proven capillary rheometer.

The compact design developed by Gneuss means that the device can be flanged in between the product pipe and is therefore ideally suited to retrofitting in existing plants.

Fig. 4: Operating principle - Gneuss Online Viscometer
5. Summary

Since introducing the Rotary Filtration Systems for extrusion applications in 1983, Gneuss has consistently developed the systems further to address both the individual processing requirements of an ever wider range of polymers as well as the wide ranging requirements or “wish list” of polymer processors and manufacturers.

The Rotary Filtration Systems from Gneuss are already well established on polymerisation processes worldwide. Experience with them has shown that they offer the plastics raw material manufacturer improvements in flexibility, automation and above all in the operating efficiency of the line, providing major economic benefits.

The use of an Online Viscometer can provide additional process control.

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