Influence of material contamination on polypropylene melt filtration using assembled and fused screens

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Abstract
The large range of polymers produced leads to their use in such diverse areas as packaging, the automotive industry, electrical applications, electronics, household appliances, building, and construction. For these applications, materials should be clean and free from contaminants, such as unintentionally cross-linked material (gels), unconverted polymers, agglomerated additives, dirt, and dust. Since 2000, the amount of plastic produced globally has increased by 5% per year. In 2019, Europe consumed 50.7 million tonnes of plastics, and demand is increasing. As production rises, so does waste, making it essential to reduce plastic waste via recycling. To be recycled, materials must be clean and free from contaminants. While numerous preparation processes in recycling can reduce contamination, the final remaining contaminants can be separated from the polymer by melt filtration. The aim of this work was thus to gain insights into the mechanisms underlying melt filtration in an extruder to determine how effective the process is depending on the type of contamination (PET particles and glass beads served as model contaminants). Additionally, behavior and filtration efficiency of two different screen-pack types were investigated. We found that rigid contaminants (i.e., glass beads) can be filtered from the melt by using screens that are finer than the particle size, but removing soft contaminants, (i.e., PET particles) requires even finer.

KEYWORDS
glass beads, melt filtration, PET, polymer filtration, screen

1 INTRODUCTION
Recycling of plastics has become increasingly important, especially as public awareness of the extent of plastic littering has grown due to photos of plastic waste floating in the oceans and media reports of microplastics in the environment. Recycling has to solve several critical issues: First, the plastic waste must be collected, and second it must be sorted, as different applications use different plastic materials and mixtures. Third, a recylcate must be produced with particular focus on purity and performance of the resulting material. In PET bottle recycling, new bottles can be made from recyclate (“bottle to bottle”) by using special recycling machinery that outputs food-grade PET.[1-2]

The majority of plastics available for recycling are materials from packaging, as these have short lifecycles compared to those, for instance, in building and...
construction and in automotive, electrical, and electronic applications. 40% of the global annual plastics consumption is packaging, in which—due to its nature—plastics are used to enclose large free volumes. This makes it very material-efficient, as the packaging uses small amounts of plastic, but also very visible in the waste streams. Recycling of packaging requires several steps to separate the reusable plastics from the waste stream. An example process is shown in Figure 1 comprises the following basic steps: sorting (e.g., separating materials such as metal and paper), cleaning (removing residues originating from the materials that were packed) and separation before any reprocessing to reduce contaminants and increase purity.[3]

Additional sorting steps are often used to separate specific plastics into streams of higher quality before the extrusion process.[1,4,5]

The amounts of contaminants should be low to achieve good overall recyclate properties. Note that the sorting and cleaning steps, though well developed, are not perfect, as some foreign polymers and contaminants, for instance, paper from labels, wooden splinters from pallets or fragments of metal staples. If the output is to be reusable, remaining contamination must be removed in the final recycling step (i.e., extrusion), and melt filtration is commonly used[6–8] to purify molten polymers. Two main techniques are applied: discontinuous and continuous filtration. The process for discontinuous melt filtration uses a fixed breaker plate and screen. These are, in principle, simple to handle and inexpensive. Continuous melt filtration uses various system combinations, for example, a filter wheel or moving ribbon system. Depending on the melt stream, replacement of the screens is triggered by time or melt pressure.[9–12]

In discontinuous melt filtration, the process must be halted when the screens are changed, and the extruder is stopped for cleaning. When filtering of the material is not the main task, this is often done in extrusion systems for safety reasons, for instance, to prevent foreign, solid materials from damaging the extrusion die.

A production stop can be avoided by using a hydraulic screen changer for a single screen package which only requires a brief pause in the flow. The filter package can be changed quickly, and the hydraulic screen changer reinserts the filters into the flow immediately.[11,13]

Continuous melt filtration is widely used in recycling, as screens can be changed without interrupting production, which allows more extensive automation and quality monitoring based on pressure readings. [11,14,15]

Melt filtration system maintenance involves cleaning and reinstalling the filters. These so-called regenerable filters can be categorized by their performance. [16,17]

In continuous polymer filtration, removable screens are used for easy cleaning and replacement. They are switched in regular intervals to optimize system performance. [18]

Several different types of melt-filtering apparatuses have been described in the literature. In the set-up presented in Kalman,[16] the polymer passes through a heated high-pressure filtering chamber with several entry and exit zones. To avoid contaminations, fresh polymer from the filtering zone is conveyed through a filter in an additional chamber between inlet port and filtering chamber.

Further, a process for separating various types of plastics[19] has been described that uses a temperature setup in which the thermoplastic component adheres to itself but not to the contaminant. Particles thus agglomerate, and their size allows separating after cooling of the mixture. This process is used to recover PVC and rubber from wire and cables.

In the recycling of PVC, even after careful separation and pre-processing, impurities may remain and deteriorate.
the material. These contaminations can be removed for better performance.\cite{6}

The approach presented in McNeice\cite{20} uses backflushing of a rotating filter. A port is installed to purge residues from the apparatus without halting the process. Further rotation of the filter causes backflushing to restart.

In Tersi et al.\cite{21} a polymer filtration apparatus was described that consists of a closed cylindrical vessel with pipes, plates, and a chamber for the fluid. The advantage of this design is based on temperature control and residence time, as the process can run continuously without any shutdown. Filters can therefore be changed easily without cooling down the apparatus.

The set-up in Hills,\cite{22} in contrast, uses a single valve to control polymer flow into and out of the filter. The single valve features mechanical stops and a shield to avoid access to running assemblies.

Generally, the melt filtration process can only remove contaminants larger than the mesh size of the screen used. Numerous patents for apparatuses and set-ups exist, but the process itself, and which materials are easy to handle, has scarcely been researched in this context.

The aim of this work was to investigate the suitability of melt filtration for removing contaminants from plastics, in this case polypropylene (PP). As rigid and soft model contaminants, glass beads and ground PET particles were used, respectively. The process data was evaluated in terms of pressure build-up, and ash content and microstructure of the filtrate were investigated to assess filtration efficiency.

\section{Materials and Methods}

The polymer used in this study was HE125MO (Borealis Polyolefine GmbH, Austria)—an easy flowing, general-purpose grade. The density was 905 kg/m$^3$ and the melt

\begin{table}[h]
\centering
\caption{Overview of materials used}
\begin{tabular}{|c|c|c|}
\hline
\textbf{Material} & \textbf{Type} & \textbf{Source} \\
\hline
Polypropylene (PP) & HE125MO & Borealis Polyolefin GmbH \\
\hline
Glass beads & 40–70 $\mu$m & Swarco AG \\
& 100–200 $\mu$m & \\
& 300–400 $\mu$m & \\
& 400–600 $\mu$m & \\
\hline
Polyethylenterephthalat (PET) & Polyclear Refresh PET 1101 & Indorama \\
& Ground 1–1.4 mm & \\
& Ground 0.75–1 mm & \\
& Ground 0.5–0.75 mm & \\
& Ground 0.2–0.5 mm & \\
& Ground <0.2 mm & \\
\hline
\end{tabular}
\end{table}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure2.png}
\caption{Schematic set-up of the apparatus used in the melt filtration experiments, including photographs and micrographs of the filters. In the experiments, assembled screens (100 $\mu$m mesh size, 27.35 mm in ø) (front side: Support mesh for taking up forces, back side: Fine mesh, which determines the filtration size) and fused screens with mesh sizes ranging from 20 $\mu$m to 250 $\mu$m were used (50× magnification, scale bar 1000 $\mu$m).}
\end{figure}
flow rate (MFR) 12 g/10 min at 230°C/2.16 kg (data taken from technical data sheet). Two different model contaminants were added to investigate melt-filtration efficiency: glass beads and ground PET particles (Table 1). The glass beads were chosen because they are relatively incompressible and should be retained by the filters, while the PET is solid at the process temperature but becomes more elastic and can be deformed under pressure.

For the PET experiments, the granules were ground to various particle sizes using screen inserts ranging from 1 mm to 0.2 mm and a Fritsch-rotary mill (Pulverisette 14). In the subsequent sieving step (Fritsch Analysette 3 Pro), various sieves with mesh sizes ranging from 1.4 mm to 0.05 mm were used in accordance with ISO 3310-1 (see Table 1).

The materials were processed through a Haake Rheocord 90 Fisons (to record pressure and temperature) with a Haake Rheomex 252 extrusion unit, which is a single-screw extruder with 19 mm screw diameter and a processing length of 28 L/D, equipped with a melt filtration device at the end of the screw before the attached die (Figure 2).

Two types of screens were used (Figure 2): assembled screens, which are stacks of filter meshes that are held together by an outer metal ring (supplied by filtertechnik.

| Screen | Screen type | Material |
|--------|-------------|----------|
| 100 μm | Assembled   | 1 wt.% 40–70 μm glass beads |
|        |             | 1 wt.% 100–200 μm glass beads |
|        |             | 1 wt.% 300–400 μm glass beads |
|        |             | 1 wt.% 400–600 μm glass beads |
|        |             | 1 wt.% ≥1 mm ground PET |
|        |             | 1 wt.% >0.71 mm/<1 mm ground PET |
|        |             | 1 wt.% >0.355 mm/<0.71 mm ground PET |
|        |             | 1 wt.% >0.180 mm/<0.250 mm ground PET |

| Screen | Fused & assembled | Material |
|--------|-------------------|----------|
| 100 μm | PP (no additional material) |

| Screen | Fused | Material |
|--------|-------|----------|
| 20 μm  |       | PP (no additional material) |
| 60 μm  |       | 1 wt.% 40–70 μm glass beads |
| 100 μm |       | 1 wt.% 100–200 μm glass beads |
| 250 μm |       | 1 wt.% 300–400 μm glass beads |
|        |       | 1 wt.% 400–600 μm glass beads |
|        |       | 1 wt.% ≥1 mm ground PET |
|        |       | 1 wt.% >0.71 mm/<1 mm ground PET |
|        |       | 1 wt.% >0.355 mm/<0.71 mm ground PET |
|        |       | 1 wt.% >0.180 mm/<0.250 mm ground PET |

| Screen | Assembled | Material |
|--------|-----------|----------|
| 100 μm | PP (no additional material) |
|        | 1 wt.% 40–70 μm glass beads |
|        | 1 wt.% 100–200 μm glass beads |
|        | 1 wt.% 300–400 μm glass beads |
|        | 1 wt.% 400–600 μm glass beads |

| Screen | Fused | Material |
|--------|-------|----------|
| 100 μm |       | 1 wt.% 40–70 μm glass beads |
|        |       | 1 wt.% 100–200 μm glass beads |
|        |       | 1 wt.% 300–400 μm glass beads |
|        |       | 1 wt.% 400–600 μm glass beads |

| Screen | Assembled | Material |
|--------|-----------|----------|
| 100 μm |           | 1 wt.% 300–400 μm glass beads |
|        |           | 2 wt.% 300–400 μm glass beads |
|        |           | 5 wt.% 300–400 μm glass beads |

TABLE 2 Configurations of the melt-filtration experiments (mesh size, type of screen, and materials used). PP was the base polymer in all cases. The assembled screens were packed only by another clamping ring, and fused screens consisted of layers sintered onto each other for additional stability; the wire mesh geometries are comparable.
Europe, Heinsberg, Germany), and fused screens, where the screen stacks are sintered into one solid package (supplied by Dostener Wire Tech Inc., Houston, Texas, USA).

2.1 Melt-filtration experiments

Each zone of the extruder was set to a particular temperature: Zone 1 to 190°C, Zone 2 to 200°C, Zones 3 and 4 (adapter) and 5 (die) to 210°C. A dry blend was prepared and fed into the intake. The experiment was run at a screw speed of 20 rpm, and data recording started when the material was filled into the hopper. The experiment was carried out either for 30 min or until the pressure before the screen reached 100 bar (the base pressure with the polymer was only 10 bar). The experiment was then stopped and the die deinstalled to collect the screen and material after the screen for further investigation.

For melt filtration, virgin PP and glass beads with particle sizes as given in Table 1 were used. 0.5 kg of each blend was prepared, where the virgin polymer was mixed as a dry blend with 1 wt.% (0.36 Vol.%) of the glass beads. To ensure that the glass beads stick to the polymer, some drops of water were added.

Subsequently, 1 wt.% (0.65 Vol.%) of the ground PET was added to PP as a dry blend, and the mixture was extruded to be melt-filtered. Table 2 summarizes the configurations of the melt-filtration experiments.

The screens used in all glass-bead and PET melt-filtration experiments were analyzed microscopically using a stereo microscope (Zeiss; Software Axio VISO) and an optical microscope (Olympus BX61) to examine the particles retained by the wires meshes. Ash content (Leco TGA701, ISO 3451-1) was determined for all glass-bead samples collected after the screens.

3 RESULTS AND DISCUSSION

The pressure-versus-time curves of the melt-filtration experiments were evaluated as illustrated in Figure 3. During the starting phase, the extrusion unit was filled with material. At the onset, pressure started to increase compared to the base pressure of the neat polymer, and

| Screen mesh size/type | Material                        | \(t_{\text{onset}}/\text{min}\) | \(\Delta t/\text{min}\) | \(t_{\text{60}}/\text{min}\) |
|-----------------------|--------------------------------|---------------------------------|--------------------------|----------------------------|
| 100 \(\mu\)m/assembled| 1 wt.% 40–70 \(\mu\)m glass\(^a\) beads | —                             | —                        | —                          |
|                       | 1 wt.% 100–200 \(\mu\)m glass beads | 2.83                          | 2.08                     | 4.91                       |
|                       | 1 wt.% 300–400 \(\mu\)m glass beads | 3.23                          | 8.38                     | 11.61                      |
|                       | 1 wt.% 400–600 \(\mu\)m glass beads | 6.13                          | 8.98                     | 15.11                      |

\(^a\)Smaller than the mesh size of the screen, and therefore no pressure increase was recorded.

| Screen mesh size/type | Material                        | After screen [%] |
|-----------------------|--------------------------------|-----------------|
| 100 \(\mu\)m/assembled| 1 wt.% 40–70 \(\mu\)m glass beads | 0.99            |
|                       | 1 wt.% 100–200 \(\mu\)m glass beads | 0.27            |
|                       | 1 wt.% 300–400 \(\mu\)m glass beads | 0.03            |
|                       | 1 wt.% 400–600 \(\mu\)m glass beads | 0.07            |

FIGURE 5 Micrographs of the five different ranges of PET particles after sieving (scale bar size 1000 \(\mu\)m)
the extruder was filled with melt and running. Subsequently, the pressure either stayed constant (e.g., for the neat polymer melt) or increased over time when particles were filtered from the melt. Of interest to our analysis were the onset point and the difference in time $\Delta t$ between the onset ($t_{\text{onset}}$) and the time at which 60 bar pressure was reached ($t_{60}$). We chose this particular value because at 60 bar the mesh remained undamaged.

### 3.1 Melt-filtration experiments using assembled screens and PP with various sizes of glass beads

Figure 4 shows the pressure curves for the melt-filtration experiments using various sizes of glass beads. The pressure curve for 40–70 $\mu$m glass beads is identical to that of the virgin polymer because the particle size of the glass beads was smaller than the mesh size of the filter, and therefore there was no material build-up on the surface of the screen. In the experiments with 100–200 $\mu$m glass beads, pressure started to increase after 3 min, and $t_{60}$ was reached after another 2 min. With the 300–400 $\mu$m glass beads, $t_{\text{onset}}$ was also at about 3 min. With the largest size of glass beads (400–600 $\mu$m), the increase in pressure occurred later, as the beads stuck together before reaching the screen. Table 3 summarizes the temporal evaluation of the melt-filtration curves.

The larger the particle size of the glass beads, the later the pressure onset and the longer until 60 bar pressure was reached (i.e., the greater $\Delta t$); for the 300–400 $\mu$m and the 400–600 $\mu$m glass beads, $\Delta t$ was very similar. This can be explained by the specific surface of the glass beads: As we used the same concentration of glass beads based on weight, the smaller ones were higher in number and exhibited a larger specific surface, and thus built up more quickly before the filter. This shortened the time until clogging of the filter occurred and the pressure started to rise, as the throughput was kept the same throughout all experiments.

To assess filtration efficiency, the ash content of the filtrate after the screen was determined (Table 4). Since the 40–70 $\mu$m glass beads were smaller than the mesh size of the screen, almost the entire quantity of glass beads added to the blend (1%) was found in the ash content. Most larger-sized beads were retained by the filter, and thus the amounts found in the filtrate were lower. That some larger beads passed through the filter can be explained in two ways: First, the mesh was not fully rigid, and thus some—possibly fractured—particles or those with a size similar to that of the mesh could be pushed through (see the results for the 100–200 $\mu$m glass beads in Table 4). Second, measurement of the ashing process is subject to uncertainty, the magnitude of which amounts to a few hundredths of a percent (see the results for the larger-sized glass beads in Table 4).

### 3.2 Melt-filtration experiments using assembled screens and PP with various sizes of PET

In the next set of experiments, PET particles as a soft material were investigated.

| Screen mesh size/type | Material | $t_{\text{onset}}$/min | $\Delta$/min | $t_{60}$/min |
|-----------------------|----------|------------------------|--------------|-------------|
| 100 $\mu$m/assembled screen | 1 wt.% $\geq$1 mm ground PET | 7.03 | 4.95 | 11.98 |
| | 1 wt.% $>$0.71 mm/$<$1 mm ground PET | 8.20 | 5.53 | 13.73 |
| | 1 wt.% $>$0.355 mm/$<$0.71 mm ground PET | 5.12 | 7.40 | 12.52 |
| | 1 wt.% $>$0.180 mm/$<$0.250 mm ground PET | 3.50 | 5.05 | 8.55 |
| | 1 wt.% $>$0.05 mm/$<$0.180 mm ground PET | 3.48 | 3.22 | 6.70 |
Microscopic investigation showed that the particle-size distributions obtained by milling were relatively similar. To yield more distinct particle sizes for our melt-filtration experiments, we used various screens to separate the milled granules into five different ranges, as shown in Figure 5.

In Figure 6, the pressure curves of the PET melt-filtration experiments are shown. The virgin PP was at around 10 bar pressure when it reached the screen. For

**Figure 7** Photographs of the assembled screens after melt filtration of various sizes of PET particles (upper) and micrographs of the cross-sections of the screens at 10× magnification (lower; scale bar 1000 μm). Microscopic analysis of the melts before and after the assembled screen at 6.5× and 12.5× magnification (sizer bar: 1000 μm)

**Figure 8** Pressure versus time curves for melt-filtration experiments using 100 μm fused screens and PP with 1 wt.% of various sizes of ground PET particles

| Screen mesh size/type | Material | After screen [%] |
|-----------------------|----------|------------------|
| 100 μm/assembled      | 1 wt.% >0.180 mm/ <0.25 mm | 0.04 |
|                       | 1 wt.% >0.05 mm/ <0.180 mm | 0.27 |

Microscopic investigation showed that the particle-size distributions obtained by milling were relatively similar. To yield more distinct particle sizes for our melt-filtration experiments, we used various screens to separate the milled granules into five different ranges, as shown in Figure 5.

In Figure 6, the pressure curves of the PET melt-filtration experiments are shown. The virgin PP was at around 10 bar pressure when it reached the screen. For
1 mm PET particles, the pressure increase started after 7 min, and with 0.5 mm and 0.2 mm PET particles a similar trend was observed. Pressure increased sooner for 0.2 mm PET particles due to their specific surface area. The temporal analysis of the experiments with ground PET is summarized in Table 5. The smaller the particle size, the sooner $t_{\text{onset}}$ and $t_{60}$ were reached. This is, again, due to the same weight percentage of PET having been added in all cases, which resulted in an increased specific surface for the smaller particles and thus in earlier pressure onset and $t_{60}$.

After the melt-filtration experiments, the assembled screens were collected and examined microscopically. As can be seen in the upper row of Figure 7, the white
residue consisting of PET particles retained by the filter formed increasingly even layers with decreasing particle size. This is also visible in the micrographs of the screen cross-sections in the lower row of Figure 7.

To assess filtration efficiency, we investigated microscopically the cooled melts before and after the screen (see Figure 8) because—unlike glass-bead content—PET content cannot be determined by ashing. Filtration worked well with 1 mm, 0.75 mm, and 0.5 mm PET particles, as demonstrated by the absence of visible particles in the melts after the screen. However, although nominally larger than the mesh size of 100 μm, PET particles in the 0.2 mm and <0.2 mm ranges were small enough to pass through the screen by deformation. Table 6 summarizes the results, giving the proportion of PET particles found in the melt after the screen: for 0.2 mm and <0.2 mm particles it amounted to 0.27% and 0.04%, respectively. This shows not only that PET was contained in the filtrate, but also the limits of image analysis, since...

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**TABLE 8** Quantities of remaining particles of 0.2 mm and <0.2 mm PET in the samples after the screen

| Screen mesh size/type | Material                  | After screen [%] |
|----------------------|---------------------------|------------------|
| 100 μm/fused screen  | 1 wt.% >0.180 mm/ <0.25 mm| 0.00             |
|                      | 1 wt.% >0.05 mm/ <0.180 mm| 0.31             |
the fact that the full volume of the melt cannot be investigated gives rise to deviations.

For comparison, and to assess the effects on filtration efficiency of a different screen structure, we also used fused screens to perform melt-filtration experiments with PET particles. Figure 9 shows the corresponding pressure curves, which—in contrast to those for the assembled screens—are relatively similar and fall within a substantially narrower range. The onset decreased with particle size (Table 7) for the same size-related reasons stated above. The difference to the assembled screens in terms of pressure build-up can be explained by the mechanical behavior: Fused screens can deform only in their entirety, and therefore the mesh size remains until failure. When assembled screens deform, the mesh size can change locally, which allows particles larger than the mesh size to pass through.

The upper row in Figure 10 shows photographs of the fused screens with PET particles after the melt filtration experiments. Cut-outs of the screens such as that shown for the <0.2 mm PET sample in the upper row of Figure 10 were examined microscopically (Figure 10, lower row). The difference to the assembled screens in terms of pressure build-up can also be explained by the difference in mechanical behavior as stated above. When assembled screens deform, their mesh size can change locally, thus giving rise to some leakage of particles larger than the mesh size. With fused screens, in contrast, the mesh size remains the same.

All fused screens were analyzed microscopically at 12.5× magnification. Figure 11 shows micrographs of the samples before and after the screen. As can be seen, filtration was successful with 1 mm, 0.75 mm, 0.5 mm, and 0.2 mm PET particles, as none were found in the samples after the screen. In comparison, with the assembled screens some particles larger than 0.2 mm passed the filter, which is not found here with the fused screens. Some particles smaller than 0.2 mm passed through the filter, but fewer than expected, most likely due to the fused screens being more rigid and retaining their mesh size upon deformation (Table 8).

### 3.3 Influence of using different amount of glass-bead loading

Figure 12 plots the pressure-versus-time curves of melt-filtration experiments using assembled screens and various proportions of glass beads of the same particle size. All curves exhibit the same time delay for the pressure increase, but differ in their slopes, because the more beads were added to the mix, the faster the filter filled up. The onset times of all three experiments are comparable, but $t_{60}$ was reached the sooner, the higher the proportion of glass beads (Table 9). Ashing of samples after the filter showed relatively comparably low glass-bead content.

| Screen mesh size/type | Material                        | Ash content of samples from glass-bead filtration experiments with PP before and after the screen |
|-----------------------|--------------------------------|---------------------------------------------------------------------------------------------------|
| 100 μm/assembled      | 1 wt.% 300–400 μm glass beads  | 0.02                                                                                               |
|                       | 2 wt.% 300–400 μm glass beads  | 0.04                                                                                               |
|                       | 5 wt.% 300–400 μm glass beads  | 0.08                                                                                               |

| Screen mesh size/type | Material                        | $t_{onset}$/min | Δ$t$/min | $t_{60}$/min |
|-----------------------|--------------------------------|----------------|----------|-------------|
| 100 μm/assembled      | 1 wt.% 300–400 μm glass beads  | 3.7            | 16.9     | 20.6        |
|                       | 2 wt.% 300–400 μm glass beads  | 3.58           | 13.52    | 17.1        |
|                       | 5 wt.% 300–400 μm glass beads  | 3.33           | 2.7      | 6.03        |
(Table 10). The screens were analyzed microscopically (Figure 13) to assess the quantity of glass beads retained.

Figure 14 plots the whole filtration time as a function of the specific surface of the particles for both PET and glass beads, to evaluate differences in filtration behavior between these two materials. The slope is much steeper for the glass beads than for the PET particles, which means that the filter fills up faster, even at comparable specific surfaces and volume fractions, which illustrates the difference in deformability between glass beads and PET particles.

### 3.4 Pressure conditions during melt filtration for assembled and fused screens with various mesh sizes

The assembled screen and the fused screens were compared in terms of pressure conditions using HE125MO at 210°C and 40 rpm screw speed.

![Figure 13](image1.png) **Figure 13** Comparison of melt-filtration experiments using assembled and fused screens with mesh size 100 μm and various sizes of glass beads

![Figure 14](image2.png) **Figure 14** Comparison of assembled and fused screens concerning t_{60} - t_{onset} (Δt) when using 1% 100–200 μm, 300–400 μm, or 400–600 μm glass beads. The trend for the assembled screen is higher compared to the fused screen due to the structure of the assembled screen
The pressure conditions depend on the mesh size of the filter: the finer the pores, the higher the pressure. In the case of the assembled screen, the pressure was lower, which was to be expected because upon bending the screen the meshes move individually and therefore the mesh size can be increased locally due to distortion. This shows, that the mesh size can change in the process, which has to be considered when designing such filtration processes.

To compare assembled and fused screens in terms of filtration efficiency, we performed experiments using the same mesh size (100 μm) and various sizes of glass beads. Glass beads sized 40–70 μm were smaller than the screen mesh size, and thus pressure increased neither for assembled nor for fused screens. The curves for the 100–200 μm glass beads start to resemble each other with the onset of the pressure increase. The curves for the 300–400 μm glass beads have the same slope but the basic pressure is higher with the fused screen. The performance of which could be improved to some extent by an additional backup plate that reduces deflection. The pressure build-up before the screen depends on both the amount and the specific surface of the contaminant to be filtered. Overall, this work has shown that solid contaminants can be filtered from the melt, but that boundary conditions such as amount, particle size and rigidity of the contaminant must be considered to yield the desired filtered polymer melt free from contamination.

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### DATA AVAILABILITY STATEMENT
Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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### TABLE 11 Temporal analysis of melt-filtration experiments using assembled and fused screen with PP and 40–70 μm, 100–200 μm, 300–400 μm, or 400–600 μm glass beads

| Screen mesh size/type | Experiment | $t_{onset}$/min | $\Delta t$/min | $t_{60}$/min |
|-----------------------|------------|----------------|----------------|-------------|
| 100 μm/ assembled     | 1 wt.% 40–70 μm glass beads | —             | —             | —           |
|                       | 1 wt.% 100–200 μm glass beads | 3.33          | 2.97           | 6.3         |
|                       | 1 wt.% 300–400 μm glass beads | 3.61          | 10.81          | 14.43       |
|                       | 1 wt.% 400–600 μm glass beads | 6.81          | 13.36          | 20.18       |
| 100 μm/ fused         | 1 wt.% 40–70 μm glass beads | —             | —             | —           |
|                       | 1 wt.% 100–200 μm glass beads | 3.18          | 1.7            | 4.88        |
|                       | 1 wt.% 300–400 μm glass beads | 4.71          | 8.23           | 12.95       |
|                       | 1 wt.% 400–600 μm glass beads | 5.33          | 11.92          | 17.25       |

### SUMMARY
This work investigated the melt filtration of polypropylene. We found that contaminants which are larger than the mesh size can be filtered successfully, with the process being more effective with rigid glass beads than with softer PET particles. For the latter, smaller screen mesh sizes are beneficial to minimize leakage of particles due to screen deformation. The more rigid fused screens retained contaminants better than the more flexible assembled screens, which we expect to be due to their deformability compared to the more rigid fused screens.
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