Vacuum Conveying Technology for Polymer Pellets

Presented by:
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Structure

• Occasion of the study
• Vacuum conveying in general
• Polymers involved
• Laboratory conveying line
• Basic test to evaluate the best hardware settings
• Comparison of different polymers
• Test results
• Conclusions
Occasion of the Study (I)

In 2007 the first presentation on pellet conveying was presented in the first step for pressure conveying, where the pellets are transported in dilute phase or in dilute phase with strands.

Based on the many discussion after the first presentation and the demand for a maintenance free pellet transport, a study on the last step, the vacuum conveying, was indicated.
After several discussion with system suppliers a common project with Motan in Isny/Germany was set up, for a better understand the vacuum conveying of pellets.

A study in 2 steps was defined and run on the pilot conveying line is Isny. It was clearly the target to develop some practical solutions for existing conveying systems under the assumption of extrusion coating.
Occasion of the Study (II)

In the first discussions, it came out that the extrusion coating application has a completely different demand to the vacuum conveying system than other applications.

For injection moulding, the main application of the smaller vacuum conveying systems, all the dust and fines has to be extruded to avoid any loss in raw material.

Injection-moulded thin wall container are much thicker than extrusion coated layers and so little heterogeneity in the walls are not so important.

For extrusion coating, it was more ore less a new definition of vacuum conveying, where only the pellets should be extruded and the dust and fines should be separated via a central filter. The system should also work operator friendly and avoid any machine stops.
Vacuum Conveying in General

Just to remember, here the phase diagram of pneumatic conveying systems.

max. 0.5 bar pressure difference for vacuum conveying

(Source: W. Siegel, Pneumatic conveying)
Pellet Shape and Conveying

In general it is known, that the pellet shape has an influence to the conveying itself.

Of course these examples are quite strange for our polyolefins world, but we should not forget that sometimes even regrind materials have to be conveyed.

So the pellet shape has to be taken into account, when designing a conveying System with all the hardware.
Some Remarks to the Conveying Performance of Pellets in the Pipe System

Vacuum conveying / material characteristics in the conveying pipe

**Horizontal material lines**
Pay attention to the maximum pipe length.
In materials with a low plastifying temperature (e.g. PE) sediments (angel hair) can form.

**Vertical material lines**
Equivalent pipe length = 2m per meter vertical line (1m vertical line corresponds to 2m horizontal line).
In case of increasing altitude ranges over 5m horizontal pipe segments have to be installed, otherwise risk of blockage (see also rising pipes).

**Bends**
Equivalent pipe length = 5m per bend (1 bend corresponds to 5m horizontal line).
In bends, higher risk of material sediments (angel hair). With very abrasive materials (e.g. glass-fibre reinforced) the life time of the bends can be shortened (by fraying).

**Inclined lines**
With inclined rising lines, the conveying material can fall out of the air stream and slip down - risk of blockage. Inclined rising lines have to be avoided under all circumstances.
Depending on the calculated “Le” length, the blower type and size have to be selected. Also the type of polymer has to be considered.
Side Channel Compressor versus Claw Pump

To reach always the right air velocity some mechanical help is needed to control the air volume.

The claw pump has a much higher efficiency and the air velocity/volume can be adjusted by the revolution speed control. But this system requires a certainly higher investment.

The Metro Flow Control tool can avoid a too high air velocity.
Function Layout of a Conveying System

If the Screen Filter would be blocked, the extruder might have to stop.
Pellet Shape and Conveying

1. Vacuum valve closed, discharge flap open → no conveying process

2. Vacuum valve closed, discharge flap closed → material requirement

3. Vacuum valve open, discharge flap closed → conveying

4. Vacuum valve closed, implosion valve open → screen cleaning through implosion → deposit on Screen Filter will fall onto the granules

In pressure balance the implosion valve will be closed.

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End of Conveying → Implosion → Filter Cleaning

vacuum valve closed
implosion valve open
→ screen cleaning

through implosion
→ deposit on Screen Filter
will fall onto the granules

By this modus, all the collected dust and fines will be extruded or will block the system in worst case scenario.
Central Filter Self Cleaning Function by Implosion

During conveying process

Filter cleaning by implosion
Central Filter

Metal Filter Screen

Hopper

Dust Bin
can be emptied during normal production
Polymers Involved

For the study typical extrusion coating grades have been selected including a HDPE and a PP, which are sometimes used in blends.

<table>
<thead>
<tr>
<th>Grade</th>
<th>MFI 190 °C / 2,16 kg</th>
<th>Density kg/m³</th>
<th>Vicat softening temperature °C</th>
<th>DSC melting point °C</th>
<th>shore hardness D</th>
<th>Copolymer Type</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>19N430</td>
<td>7,5</td>
<td>920</td>
<td>88</td>
<td>108</td>
<td>47</td>
<td></td>
<td>LDPE</td>
</tr>
<tr>
<td>19N430 (High dust level)</td>
<td>7,5</td>
<td>920</td>
<td>88</td>
<td>108</td>
<td>47</td>
<td></td>
<td>LDPE - Dusty</td>
</tr>
<tr>
<td>M21N430</td>
<td>7,5</td>
<td>921</td>
<td>90</td>
<td>108</td>
<td>48</td>
<td>1,2% MAA **</td>
<td>Low Acid</td>
</tr>
<tr>
<td>M24N430</td>
<td>7,5</td>
<td>923</td>
<td></td>
<td>105</td>
<td></td>
<td>3,8% MAA **</td>
<td>Medium Acid</td>
</tr>
<tr>
<td>ELTEX PF1315AA</td>
<td>15</td>
<td>913</td>
<td>97 / 115</td>
<td></td>
<td></td>
<td></td>
<td>mPE</td>
</tr>
<tr>
<td>HD 6070 FA</td>
<td>7,6</td>
<td>960</td>
<td>127</td>
<td>132</td>
<td>68</td>
<td></td>
<td>HDPE</td>
</tr>
<tr>
<td>PP 100 GA 37</td>
<td>37 *</td>
<td>903</td>
<td>162 - 165</td>
<td></td>
<td></td>
<td></td>
<td>PP</td>
</tr>
</tbody>
</table>

* 230 °C / 2,16 kg  
** MAA = methacrylic acid

** This sample has been taken out of the system just before the normal dedusting step.
Polymers Involved

Beside the “normal” properties, bulk density and pellet size were more important.
Laboratory Conveying Line

The laboratory line from Motan in Isny/Germany was used for this study.

Following parameters were selected:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe diameter</td>
<td>45 mm (42 mm inner diameter)</td>
</tr>
<tr>
<td>Length of pipe in total</td>
<td>100 m</td>
</tr>
<tr>
<td>Vacuum pump</td>
<td>Claw pump with adjustable revolution speed</td>
</tr>
<tr>
<td>Air velocity</td>
<td>~ 21 m/s</td>
</tr>
<tr>
<td>Air volume</td>
<td>105 Nm³/h</td>
</tr>
</tbody>
</table>
2 loops of 50 m were combined to the 100 m test length
Laboratory Conveying Line

Hopper Loader

Central Filter

Claw Pump
Basic Test to Evaluate the Best Hardware Settings

Different filters for the hopper loader were tested to evaluate their influence.

The target was clearly to modify the hopper loader that all pellets will be extruded and all the dust and fines will go to the central filter.

By this way a nearly maintenance free hopper loader should be developed.

It is critical to avoid dust and fines in the extruder hopper because they can block the hopper or screw, forming gels or other heterogeneities, which results in a bad melt quality.

This is important, as the coating thickness trend is to go thinner, i.e. below 10 µm. To give a reference, a human hair is 50-60 µm.
# Basic Test to Evaluate the Best Hardware Settings

<table>
<thead>
<tr>
<th>Code</th>
<th>pipe length</th>
<th>air velocity</th>
<th>filter type</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDPE 500 μm</td>
<td>100</td>
<td>21</td>
<td>500 μm</td>
<td>a bit finer than the basic filter</td>
</tr>
<tr>
<td>LDPE 1.200 μm</td>
<td>100</td>
<td>21</td>
<td>1.200 μm</td>
<td>most common used filter</td>
</tr>
<tr>
<td>LDPE 2.000 μm</td>
<td>100</td>
<td>21</td>
<td>2.000 μm</td>
<td>a bit wider than the basic filter</td>
</tr>
<tr>
<td>LDPE no filter</td>
<td>100</td>
<td>21</td>
<td>no filter</td>
<td>the filter was removed, but some pellets jumped over to the central filter</td>
</tr>
<tr>
<td>LDPE 43 m/s</td>
<td>100</td>
<td>43</td>
<td>no filter</td>
<td>with double the speed (not recommended) much more pellets jumped over to the central filter</td>
</tr>
<tr>
<td>LDPE 5 m</td>
<td>5</td>
<td>21</td>
<td>no filter</td>
<td>here we simulated a very short distance</td>
</tr>
<tr>
<td>LDPE dusty</td>
<td>100</td>
<td>21</td>
<td>no filter, but modified</td>
<td>the hopper loader was modified by more headroom and no pellets jumped over</td>
</tr>
</tbody>
</table>
Different Types of Hopper Loader Filter

Empty loader                Perforated metal plate                With filter
Different Screen Filter for the Trials

500 µm  1.200 µm  2.000 µm
Screen Filter from the Trials - Some Collected Fines

After each conveying trial we took the screen filters out of the hopper loader. We could always find some fines, which have not been cleaned out by implosion.
Standard Hopper Loader in Operation

Conveying

Fines on the screen filter

Fines on the glass wall
Modified Hopper Loader in Operation

The headroom was enlarged

A special inlet was designed to hold back only the granules
## Basic Test to Evaluate the Best Hardware Settings

<table>
<thead>
<tr>
<th>Code</th>
<th>pipe length</th>
<th>air velocity</th>
<th>filter type</th>
<th>conveyed amount</th>
<th>collected in the Central Filter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>m</td>
<td>m/s</td>
<td>kg</td>
<td>total</td>
<td>pellets only</td>
</tr>
<tr>
<td>LDPE 500 µm</td>
<td>100</td>
<td>21</td>
<td>500 µm</td>
<td>1068</td>
<td>30</td>
</tr>
<tr>
<td>LDPE 1.200 µm</td>
<td>100</td>
<td>21</td>
<td>1.200 µm</td>
<td>856</td>
<td>12</td>
</tr>
<tr>
<td>LDPE 2.000 µm</td>
<td>100</td>
<td>21</td>
<td>2.000 µm</td>
<td>502</td>
<td>8</td>
</tr>
<tr>
<td>LDPE no filter</td>
<td>100</td>
<td>21</td>
<td>no filter</td>
<td>516</td>
<td>17</td>
</tr>
<tr>
<td>LDPE 43 m/s</td>
<td>100</td>
<td>43</td>
<td>no filter</td>
<td>502</td>
<td>54</td>
</tr>
<tr>
<td>LDPE 5 m</td>
<td>5</td>
<td>21</td>
<td>no filter</td>
<td>537</td>
<td>22</td>
</tr>
<tr>
<td>LDPE dusty</td>
<td>100</td>
<td>21</td>
<td>no filter, but modified</td>
<td>357</td>
<td>30</td>
</tr>
</tbody>
</table>
Basic Test to Evaluate the Best Hardware Settings

With the filter less and modified hopper loader even 84 ppm dust and fines could be extracted from the very dusty LDPE. So this setting was used for the further tests.

- Doubling the air velocity increased the collected dust
- Reducing the pipe length reduced the collected dust
Comparison of Different Polymers

With this modified hardware setting we conveyed different polymers, to understand their behaviour. Beside the LDPE, acid Copolymers and mPE also a HDPE and a homo-PP were tested. Only from the dusty LDPE a smaller volume was conveyed compared to the other polymers.
Comparison of Different Polymers

Depending on the pellet geometry and physical properties of the polymers a different throughput was observed.
Comparison of Different Polymers

The tests showed clearly that with a filter less hopper loader over 100 m distance, the dust level had more the tendency to decrease, even with the very dusty LDPE.

** This sample has been taken out of the system just before the normal de-dusting step.
Comparison of Different Polymers

With the modified hopper loader we could collect a huge amount of dust and fines from the LDPE, which had an increased, unusual high dust level.
Comparison of Different Polymers

When calculating the generated dust during conveying, the acid copolymers showed a strange value. May be some dust stacked to the wall of the pipes, due to the polar character. But that would be a topic for another study.
Conclusions

- In the first part of the study the target was reached, to modify an existing hopper loader to deliver only the pellets to the extruder and retain most of the dust and fines in an easy-to-empty central filter.

- By a simple modification of replacing the hopper loader and adapting the air velocity, most of the existing conveying installations could be optimised.

- In the second part of the study different polymers were compared. They were all conveyed under the same conditions.
  - HDPE had the highest throughput compared to mPE, with the lowest one.
  - Vacuum conveying systems have definitely to be fine tuned corresponding to the polymer to be transported.

- As a result, if the same hopper loaders are used to convey different polymers, different settings may be necessary.
Acknowledgement

The author would like to thank the Motan team for operating the pilot line in such an unusual way. Specifically Klaus Höller and Ralph Schäfer, who contributed a lot in theoretical and practical work to reach the target. Also the team in the workshop for their flexibility in modifying the hardware on short notice.

Many thanks also to the co-author, who contributed with all the detailed information to visualise this dusty topic in an interesting way.

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Thank you for your attention!!

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