Improved process performance of flat dies by a much wider die gap operation window and a new surface finish of the die body

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Part 1

Improved die gap operating window
In the extrusion coating technology the flat dies are always the handover tool of the melt from the extruder to the substrate, but in a well distributed way.

So it is just normal that there are different solutions of these flat dies around the world.

All dies have an opening slot, the die gap over the operating width, even if the internal design is totally different.
So this paper will not discuss the various types of flat dies and the length of the die land, the last flow channel just before the exit.

- T-slot
- fish-tail
- coat-hanger
- dual slot
- multiple manifold single slot
- T-slot internal deckling
The die gaps, we found in the market, were in a range from 0.3 up to 1.4 mm.

The draw down ratio was for a certain period discussed everywhere. A lot of recommendations for different polymers were given.

\[
\text{Draw Down Ratio} = \frac{\text{Die gap in } \mu\text{m}}{\text{Coating thickness in } \mu\text{m}}
\]
Here some examples of draw down ratios, as we found more than 2 different philosophies.

Draw Down Ratio = \frac{\text{Die gap in } \mu\text{m}}{\text{Coating thickness in } \mu\text{m}}

<table>
<thead>
<tr>
<th>die gap in \mu\text{m}</th>
<th>1000</th>
<th>1000</th>
<th>700</th>
<th>700</th>
<th>400</th>
<th>400</th>
</tr>
</thead>
<tbody>
<tr>
<td>coating thickness in \mu\text{m}</td>
<td>100</td>
<td>10</td>
<td>100</td>
<td>10</td>
<td>100</td>
<td>10</td>
</tr>
<tr>
<td>draw down ratio</td>
<td>10</td>
<td>100</td>
<td>7</td>
<td>70</td>
<td>4</td>
<td>40</td>
</tr>
</tbody>
</table>

It was common understanding to have a low draw down ratio, to allow a good die control and good coating profile in cross direction!! but .......

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But different types of polymers have a different behavior, which leads to a different **die swell**.
So the draw down ratio theory was in competition with the die swell, which is not so easy to measure or visualize.

To ask for are a die gap recommendation was nearly impossible, as there were a lot of different opinions.

By experience on our laboratory line, a die gap of 1 to 1.2 mm gave good results and good coating weight profiles for LDPE!
The die bolts realize an operating window for the die gap of ± 0.2 mm around the mechanical fixed basic gap.
By experience on our laboratory line a die gap of 1 to 1.2 mm gave good results and coating weight profiles for LDPE, but not for all other polymers!

So we had very often to adjust the basic die gap, to a smaller value, to be able to run other polymers.

This basic adjustment was very time consuming and is only acceptable for a laboratory coating line.
Based on this experience there was the idea to enlarge the movement window for the die gap in an easy and convenient way.

The die bolt movement capacity could not be enlarged, as this would mean a lower resolution for the final cross direction thickness control.

So the distance holder was developed further to a second heating bolt, the so called Spacer, with the movement from the temperature related enlargement of the steel as well.
Automatic die with a fast die gap base adjustment

The spacers realize an operating window for the basic gap of +/- 0.2 mm around the mechanical fixed base position.
Enlarged die gap operating window for the die gap

By setting the temperature of the spacers, we could achieve different basic die gaps.

- Die gap 0.7 mm at medium spacer temperature
- Die gap 0.5 mm at low spacer temperature
- Die gap 0.9 mm at high spacer temperature
Total operating window of spacer and die bolt

Die gap at various spacer and die bolt temperatures in mm

<table>
<thead>
<tr>
<th>Spacer-temperature</th>
<th>die bolt temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>low</td>
</tr>
<tr>
<td>high</td>
<td>0,3</td>
</tr>
<tr>
<td>medium</td>
<td>0,5</td>
</tr>
<tr>
<td>low</td>
<td>0,7</td>
</tr>
</tbody>
</table>
How to find the best die gap

The speed how fast and stable a good cross profile can be reached is a very good indicator to identify the best operating window.

In addition to this, we have installed a pressure sensor at the die inlet channel. A too high internal melt pressure indicates a high die swell, which can lead to an uneven cross profile.
Part 2

The new surface finish
In the extrusion coating history the materials of the flat-dies have gone through a long evolution.

Beside the base material of the die also the surface finish technology made its own evolution.

And there is still another step of evolution to be mentioned here, which goes in hand with the improved performance of the enlarged die operating window technology, described in the few slides before.
Here some well known surfaces

- standard steel barefoot
- stainless steel barefoot
- stainless steel chromium plated
- steel chromium plated
- steel nickel plated
- ...

The demand profiles and/or the applications were extremely different.
Some requested properties

- protection against corrosion
- low or no tendency for deposits
- easy flow of the polymer inside the die
- good purging behaviour
- low tendency for die lines
- hard and robust surface, not to be damaged during mechanical cleaning
- ….
Another property, which is tricky to measure is the friction between melt and surface.

Some people report about flow problems or even a rough shark skin of the product. This is the well known problem of melt fracture.

Also the micro cracks of the chromium surface are made responsible for some purging or flow problems, as there are always some polymer deposits sitting in the micro cracks.
The solution

When we got our new die, now more than 1 year ago, we took the chance to get the new surface.

This surface reduced dramatically or eliminated nearly all known problems reported before.

It is a kind of chromium nitride plasma coating, which delivers this performance.
The rainbow effect from the surface of this die lip indicates that it is something magic!
Summary 1/2

• With the adjustable basic die gap via the spacer temperature different polymers can be coated in good quality without mechanical adjustments on the die.

• With monitoring and influencing the melt pressure in the die, we have identified a new tool to improve the quality and processability.
Summary 2/2

- **The behavior of the melt pressure in the die will be topic of another study**

- **The new die surface supports a smoother production and less deposits, die lines and cleaning problems**

- **The new die generation allows a better cleaning, due to the larger „cleaning gap“**
If you don’t believe, come and see.
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Thank you for your Attention!

Sorry for so much text and not enough pictures.

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