Reduction of sharkskin effect on Battery Separator Film

What is sharkskin?

Sharkskin is a widespread and known melt defect that appears at the die exit. The place of origin need not necessarily be the die or the die outlet. Frequently, the causes are also found in the plasticization of the extruder or the melt guidance. Highly viscous materials, or those that are poorly plasticized tend to cause flow instabilities. These failures of product homogeneity, often referred to as "melt fracture" or “sharkskin” usually compromise the quality of the extrudate so much that it becomes unusable for the application. This type of surface defect that affects the geometry and dimensional accuracy of the product not significantly has a big impact on the optical and mechanical properties.

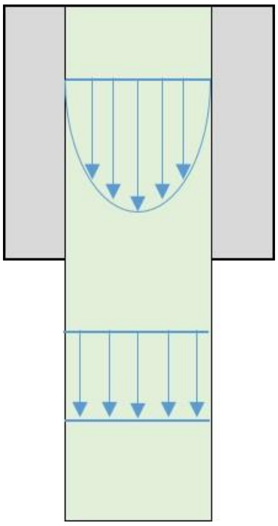

Figure 1: scheme of velocity profile within the extrudate

High differences of the flow velocity at the die wall (wall adhering) and in the middle of the flow channel can especially cause this defect to occur. When the melt exits the die, it needs elastic properties to deal with the changed velocity profile from parabolic to plug flow. Depending on the rheological properties of the melt, it can rip at the surface and a flaked structure forms. Even after stretching this defect can be recognized in the film, in extreme cases it can lead to problems within the film stretching process such as film breaks.

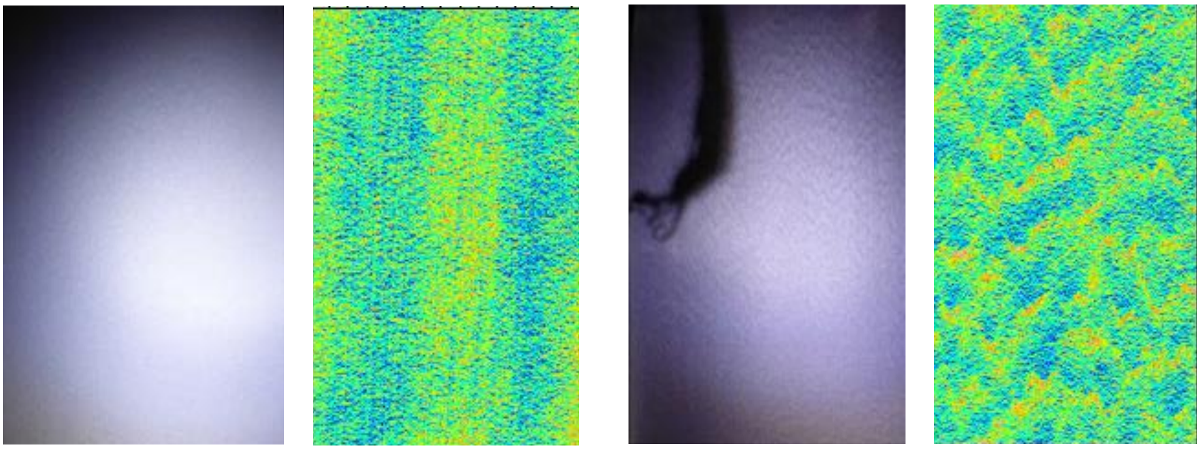

Figure 2: left: extrudate without defects (photo and confocal microscopy; magnification ratio 50); right: extrudate with sharkskin (photo and confocal microscopy; magnification ratio 50)

What can be done against sharkskin?

In general there are several ways to avoid or reduce sharkskin. One is to reduce the melt’s viscosity. This can take place due to higher temperatures, higher amount of solvent, by optimizing the recipe or by adding flow additives. Materials are often limited to higher temperature, changing the material may lead to different film properties and therefore all relevant tests of the film has to be redone and the process readjusted, an enormous effort.

Another approach is to manage the velocity directly. The easiest way to achieve this is by reducing the mass throughput. It is obvious that this course of action is economically unviable. A new die design with a shorter die land or a bigger radius at the melt exit can have negative consequences, such as more die swell, or faster plate-out at the die lips.

It is also possible to induce wall slippage and therefore ease the changeover to plug flow. This can be done with a suitable die surface or by using flow additive. Variating the properties of the die surface can be achieved by coating or finishing, the topology as well as the surface tension are issues. There is a considerable difference according to costs but also in the surface sensitivity.

<u>What tests were carried out?</u>
In order to find out if it is possible to influence the sharkskin effect, it is very important to create conditions that are as practical as possible. For this reason, a special die tool has been developed with replaceable die nozzle inserts.

The standard hard chrome plating was used as reference. In addition an additive was tested.

The tests showed a good accordance to literature in terms of known theory and practice. The dependency of the sharkskin to the process-settings can be seen in the following table.

Table 1: Dependency of process parameters to sharkskin

Parameter		**Appearance of sharkskin**
Temperature of the die	↑	↓
Heating of the die lip	↑	↓
Length of die land	↓	↓
Content of solvent	↑	↓
Mass throughput	↓	↓
Screwspeed		→

Based on these conclusions, five process-settings were selected for further tests, some of which encouraged sharkskin, and others where it shouldn't normally occur. Therefore, temperatures of the die, heating of the die lip, as well as the content of solvent were varied. Mass throughput and screw-speed were kept constant. For the die design of the further tests, a die with longer die land was chosen, since more sharkskin can be expected in this case.

<u>What's the conclusion from the trials?</u>
The die coatings used for the trials were very different. They therefore showed very different performance regarding the reduction of sharkskin. While some coatings even supported sharkskin, others prevented it successfully. In part, curtailments regarding price or tool life have to be accepted.

In case of questions realted to sharkskin or the coatings tested, please feel free to contact the authors.

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