BOPE: a challenge for extrusion

Why PE?

Packaging made from polyethylene is currently a widely discussed topic – in the media, in the technical press as well as at Brückner. As known, packaging has to be able to meet many demands: looking good, being printable and tearproof. Additionaly, it provides a barrier for oxygen and humidity to preserve food – without the use of preserving additives. And: it should be easy to recycle. Unfortunately, the recyclability is contradictory to all the other requirements – especially if a multi-layer composite is used. This is where PE fits in.

There have been various PE-related R&D projects at Brückner's technology center. Here are some of the most important findings:

PE is not equal to PE – neither to PP

From the same monomer (ethene), different substances classified by densities and branching can be achieved due to different polymerization methods. Besides high molecular PE types, which are for example used in the battery separator film production, mainly two of these subsections are interesting from Brückner's point of view: HDPE and LLDPE.

HDPE (or PE-HD – high density) is definied by a density between 0,94 g/cm³ and 0,97 g/cm³. It has a low degree of branching. LLDPE (or PE-LLD – linear low density) is a substantially linear polymer with significant numbers of short branches, commonly made by copolymerization. These short branches keep a distance between the polymer chains resulting in a density range of 0,915 – 0,935 g/cm³.

Regarding the chemical structure, PP is similar to PE. Both are polyolefines. From film producer's side there's the wish of hybrid BOPP/BOPE lines or to upgrade older BOPP lines in a way to process also BOPE.

In the last couple of years, several tests have been made to process BOPE at existing PP lines. Regarding the extrusion system the same picture arose frequently: The PE requires a higher torque of the motor, which is not designed for this. Therefore, the only way was to run the extruder with a much lower degree of filling compared to the processing of PP. This approach however leads to higher mass temperature due to higher shear. Additionally, the pressure built up in the melt pipes and the die was massive in some cases, limiting the process. It was possible to process PE on several lines admittedly with considerably lower throughput compared to PP. To reach a throughput and mass temperature closer to the PP-benchmark, several R&D-projects have been carried out since 2019.

BOPE extrusion rheology

The topic was to characterize the flow properties of different PE melts, paying additional attention to possible flow instabilities such as sharkskin. Flow instabilities can influence the design of dies or melt pipes because the material behaves different when exceeding an assigned stress. Mainly they lead to surface defects, which are not acceptable for our customers.

The differences in the viscosity of the materials are remarkable. Within ten analysed materials the zero viscosity differs at a factor 12. This means 12 times the pressure in the melt pipe with same processing parameters. In other words: While there is a pressure build up of about 20 bar in the die pipe with one material, the line is going to shut down because of maximum pressure with another. The comparison also shows that our standard PP is quite exactly in the middle of these extremes. The shear thinning behavior on the other hand is much stronger within the PP, resulting in a lower viscosity at higher shear rates than any of the analysed PE materials.

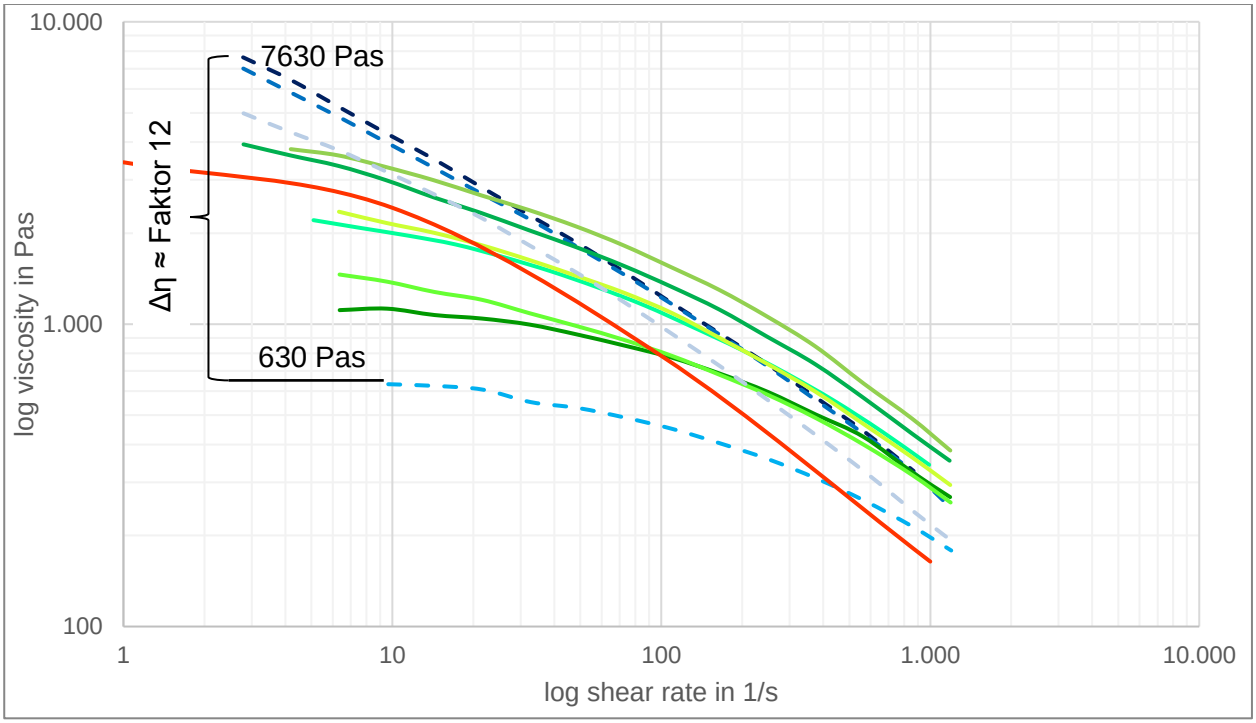

Figure 1: viscosity curves of different materials: HDPE types in blue, LLDPE types in green, for comparison the standard PP in red

Depending on the process conditions, some of the analysed materials showed the tendency to surface defects.

BOPE extrusion twinscrew

In the context of this project tests with twinscrew extruders were carried out and the design of the screws used for PP processing was adjusted to enable also processing of PE. In general, it is possible to process PE with screws optimized for PP. But since PE behaves completely different, this would lead to massive losses in material throughput.

The differences between PP and PE cause multiple effects: Since PE usually shows a much higher viscosity compared to PP, the torque of the extruder increases, as well as the melt temperature and the pressure.

A screw design for PP and PE was successfully developed. Compared to the PP optimized screws there is hardly any loss for PP, while PE can also be processed well. For higher throughputs with PE, a stronger extruder drive than standard is necessary.

BOPE extrusion filter die

As aforementioned, the distribution of the melt at the die exit is different with PP and PE while the pressure in the melt pipe increases with PE. Hence, based on the rheological data, die and melt pipe were redesigned.

There is good news according to the die pipes and filters: Since PP and LLDPE behave not too different in the lower shear stress region, both materials can be processed with the same set of pipes and filters.

A hybrid design for the die is possible within restrictions. Due to the different viscosity also the melt distribution at the die exit is changed, which significantly influences the thickness of the later film. A compromise regarding to the thickness distribution is impossible. So for hybrid lines processing HDPE, too, a second die is included in the standard delivery and the customer has to change the die when changing material.

The rheological harmonization of the raw material by the supplier is necessary to avoid this reorganization of the line and the need of additional parts.

Conclusion and prospects

Biaxially oriented PE films do have a great potential for the future and therefore draw the market's interest. From the extrusion point of view, the material is a challenge, that can be mastered. Still, it is necessary to differ the PE kinds precisely. The unobstructed processing on a hybrid line requires optimized screw geometry as well as readjusted melt pipes, filters and dies.

Numerous raw material suppliers are developing new PE kinds. The aim is to get materials, with rheological properties more similar to PP. The better this succeeds, the less limitations and throughput reductions must be taken into account.

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