Innovative Process Cost Optimization

PVC Window Profiles. Functionalized calcium carbonates allow significantly higher levels of fillers in co-extrusion, whilst at the same time improving processing and the surface finish of PVC window profiles. Finally, a high filler level combined with specific co-extrusion technology and an increased use of recyclate results in considerable cost saving potential.

With a market share of 57 % producers of plastic window frames are in a comfortable position. Despite this they are facing a range of challenges. Rising costs for crude oil products such as PVC, industrial metals such as zinc as well as fats for lubricants are forcing up the prices of PVC dry blends (a mixture of polymer powder and additives). An additional factor is the shortage of raw materials such as titanium dioxide which is needed for white window profiles. Manufacturers have to react to increasing price pressures, demands in respect of sustainability and the growing use of recyclate.

One approach to solving these problems is offered by co-extrusion with the addition of calcium carbonate and increased quantities of recyclate. Co-extrusion allows a cost effective choice of raw materials for window profiles that can be produced with core/skin technology. Color and gloss of the end product are defined by the weathering resistant exterior layer (skin) whilst the core only has to satisfy basic visual requirements.

PVC windows are of course available in white, like the ones in this office building, but there are also other finishes, e.g. wood effect (photo: Baerlocher)

The price difference between the dry blends for the exterior layer and the core is considerable. Thus, co-extrusion technologies are a decisive factor for the cost saving potential per meter of profile. Co-extrusion allows to adjust a ratio of materials in the core to the exterior layer of around 30 to 70 %. Compared to mono-extrusion it is possible to achieve raw material cost savings of 6 to 10 % for the same length of profile.

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Influences on Costs and Quality

Tooling manufacturers have reacted to market demand and offer co-extrusion technologies matched to the different requirements of extrusion companies. Greiner Extrusion GmbH, Nussbach, Austria, has three processing technologies for this: Core, layer and combination technologies **(Fig. 1)**, of which the latter is the newest.

Co-extrusion tooling also influences costs and quality. This can be seen for instance in the uniformity of co-extrusion layer thicknesses where variations lead to increased usage of expensive exterior material. Changing the ratio of core to exterior material at typical outputs by just 5 % makes it possible to achieve yearly savings of EUR 10,000 to 20,000 per extrusion line.

An FEM simulation of the co-extrusion die allows the tooling manufacturer to analyze for instance the wall shear stress, overall pressure **(Figs. 2 and 3)** as well as relative flow rates during the design process. Optimizing these factors prevents sectional color differences and makes a critical contribution to uniform profile quality.

Today extruder manufacturers offer a very wide range of different systems for co-extrusion: parallel and conical twin screw extruders, co-extruders for integrated extrusion systems as well as column, piggyback and tandem extrusion solutions.

The tried and trusted parallel twin screw extruders of the 32D series from KraussMaffei Berstorff GmbH, Munich, Germany, provide a high degree of process flexibility in the mid to high output ranges. The processing concept guarantees optimal melt homogeneity and provides for the processing of different formulations with a single screw geometry.

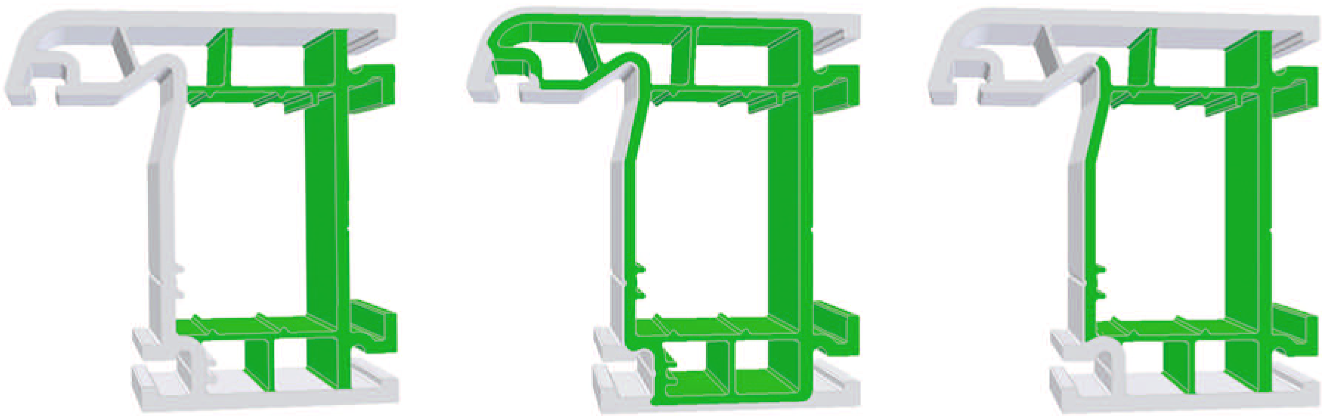

Fig 1. Co-extrusion using core, layer and combination technologies (from left to right) (picture: Greiner Extrusion)

In order to reach the same degree of processing flexibility as the parallel extruders, the processing length of the conical twin screw extruders has been substantially increased compared to the previous range, particularly in the pre-warming section. Alongside reliable material degassing this leads to an optimal homogeneity of the melt. The longer metering zone helps to higher pressure stability up to 500 bar over the entire output range of the extruder which is particularly important for co-extrusion.

An extruder combination of a primary parallel KMD 114-32/P extruder and two conical KMD 63K/P co-extruders is used for the combination technology with dual profile output. The core layer (approx. 55 % of the total output) is processed on the primary parallel extruder and the exterior layer on the two conical co-extruders. Total output is 800 to 1,000 kg/h.

Another possible extruder combination, which is mainly used for core and layer technologies, can be seen in **Figure 4.** This arrangement comprises a primary parallel KMD 90-32/P twin screw extruder and a conical KMD 63K/P twin screw as the co-extruder. Whilst with core technology the co-extruder is used for the extrusion of the core material, with layer technology the same machine produces the exterior skin of the profile. This extruder combination has an output range between 450 and 550 kg/h.

Optimizing with Calcium Carbonate

High quality calcium carbonates from Omya International AG, Oftringen, Switzerland, have been gaining significance as functional additives for many years. As documented in this research project, such products allow window profiles to be produced with much higher filler loadings than have generally been used up until now. Thus increasing raw material prices can – at least in part – be offset whilst meeting product quality requirements.

Due to their lengthened preheating zone and customized screw configurations modern extruders can also disperse higher loadings of calcium carbonate very well – a prerequisite in order to guarantee the mechanical and visual specifications.

The use of higher levels of an optimal calcium carbonate improves a number of process parameters and has a smoothing effect on product variations. It also improves the homogeneity of the melt. Differences of the temperature distribution in the melt, which might occur during changes in flow direction, can be effectively reduced.

In addition, the surface finish of the profile is enhanced since there is less inhomogeneity such as streaks and gloss differences within and between profiles.

In calculating potential savings, account needs to be taken of the fact that with higher levels of calcium carbonate and the same wall thicknesses the weight per meter of profile also rises. Due to the increased bulk density of the PVC dryblend, which results from a higher calcium carbonate content, as well as the volumetric parameters of the extruder, however, the output length of profile remains roughly constant at unchanged screw speed.

Calcium carbonate also improves heat removal in the downstream equipment. The more rapid cooling of the profiles allows higher haul-off speeds and thus the extruder screw speed can be raised. In the end this leads to an increased output of profile.

The Central Role of the Stabilizer Systems

As in the majority of PVC applications, stabilizers play a central role in the co-extrusion of window profiles. These multi-component systems such as the ones marketed by Baerlocher GmbH, Unterschleissheim, Germany, stabilize the PVC during processing in the hot processing equipment, control melt flow and determine surface finish and color of the end product. Various raw materials are brought together to make so called one-packs and are appropriately adjusted to individual customer requirements.

There has been a move to calcium/zinc systems over the last few years in the EU window profile market – in part due to →

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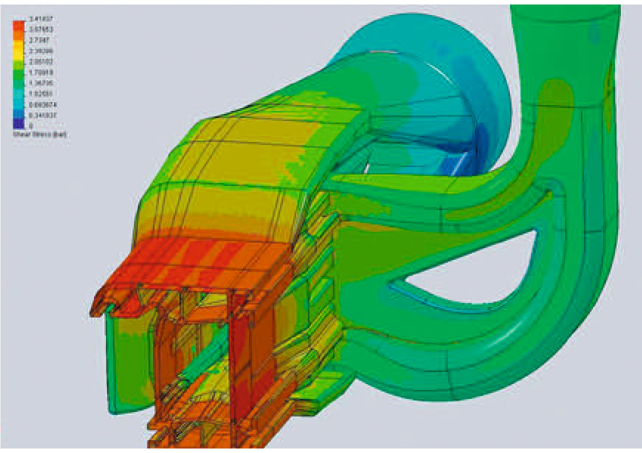

Fig 2. FEM simulation of wall shear stress in the co-extrusion die
(picture: Greiner Extrusion)

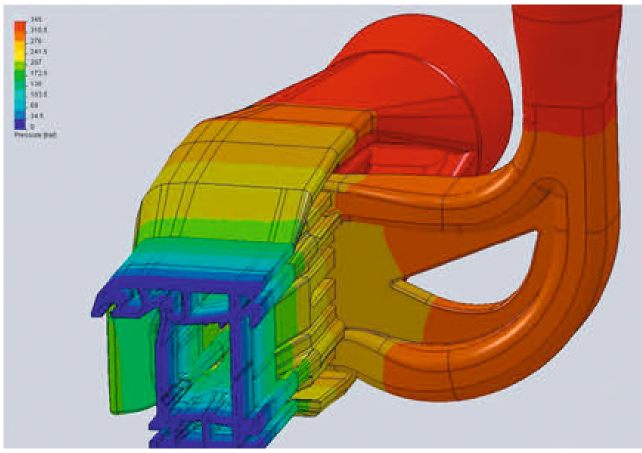

Fig 3. FEM simulation of pressure distribution in the co-extrusion die
(picture: Greiner Extrusion)

the voluntary commitment "Vinyl 2010". There are, however, also cost advantages from the use of calcium/zinc stabilizers in comparison to classic lead systems. This applies in particular to the co-extruded core layer, since the use of color co-stabilizers is not needed.

Controllable Processing

Within the framework of an extensive series of investigations by the multi-disciplinary network formed by the companies Baerlocher, Greiner Extrusion, Omya and KraussMaffei Berstorff, formulations with raised calcium carbonate loadings were optimized. Stabilization was provided by a modern calcium/zinc one-pack. In a defined machine environment and with constant tooling temperatures various PVC window profile formulations with different calcium carbonate loadings were co-extruded.

Since not every profile manufacturer has access to sufficient quantities of recyclate for the core formulations, highly filled core systems were used and combined with special formulations for the exterior profile layer. The objective was to achieve cost savings not only in the raw materials, but also in the window profile manufacturing process without allowing quality to be compromised.

Results showed that formulations with a calcium carbonate content of up to 20 phr could be processed without difficulties. Adjustments to the lubricant system allowed optimal plastification to be achieved even at raised calcium carbonate levels.

Profiles Meet Specifications

The formulations investigated were able to prove themselves in respect of dimensional stability, shrinkage and weight per meter. Increasing E-modulus, which is linearly dependent on calcium carbonate loading, resulted in greater profile stiffness. Shrinkage was within the acceptable region of up to -1.8 % and decreased with increasing mineral content.

No changes in heat storage tests were seen as a result of the increased loadings of calcium carbonate. Through the choice of the correct calcium/zinc stabilizer the results for the thermostability (measured as DHC value) met the 40 minutes typically required for both the exterior and core layers. Fine calcium carbonate grades produced an additional increase in the DHC values.

As part of the investigations, the notched impact values and corner weld strengths of the profiles produced were measured. A reduction in impact strength with increasing mineral filler

Fig 4. Extruder combination of a primary parallel twin screw extruder and conical twin screw extruder
(photo: KraussMaffei Berstorff)

content can be seen at a constant melt temperature, but all the values determined all lay above the minimum requirement of 45 kJ/m^2. Falling dart impact tests were also passed. However, increasing the melt temperature as well as the use of finer calcium carbonate led to a clear improvement in notched impact strength. Corner weld strength was significantly above the minimum value of 2,244 N calculated for the profile.

Visual factors are not important for the core formulation and it was the exterior layer that was assessed in this respect. The color values were only slightly affected by the quantity of calcium carbonate. However, the grade of calcium carbonate had a large influence. Through the use of suitable pigment toners it was possible to meet the profile color specifications in every case.

In general, gloss decreases with higher addition rates of mineral fillers. Moving to finer calcium carbonate, however, has a positive effect on gloss. In this way profile gloss can – in combination with an optimized lubricant system – be held stable, even when the quantities of mineral filler are increased.

Conclusion

Manufacturers of window profiles can adapt to the challenges of the market through the use of co-extrusion. Low cost core systems and the controlled addition of suitable calcium carbonate contribute to cost reduction. The payback on the increased technological overhead can be individually calculated using a special program from Greiner Extrusion. ■

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