Direct Route to the PVC Profile

Extrusion of Rigid PVC without Dry Blend Production

Before the direct extrusion of profiles made of polyvinyl chloride was developed, it was previously necessary to produce a dry blend. This process is expensive and energy-intensive and, in contrast to direct extrusion, discontinuous. The direct extrusion of PVC using planetary roller extruders promises an improvement. In addition to soft PVC, rigid PVC can also be processed in this way with a few adjustments.

The direct extrusion of PVC profiles on planetary roller extruders can save costs and energy and simplify the process

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Polyvinyl chloride (PVC) is one of the most used plastics. PVC is mainly used in the construction sector for the manufacture of pipes and fittings, rigid profiles or window profiles, rigid foils and plates, cables, floor coverings etc. [1]. However, the manufacturing process of PVC differs significantly from that of other thermoplastics. Before the actual processing, a dry blend must be produced in a discontinuous batch mixing process. Only then the PVC can be processed on an extruder into semi-finished products such as films, sheets, profiles or pipes. Dry blend production is generally carried out in heating/cooling mixers (HCM). By rotation of the mixing tool, the powdery components of the PVC formulation are mixed and heated, and additives can diffuse into the PVC grain.

This dry blend manufacturing process is energy-intensive and expensive. Another disadvantage of classic PVC processing »

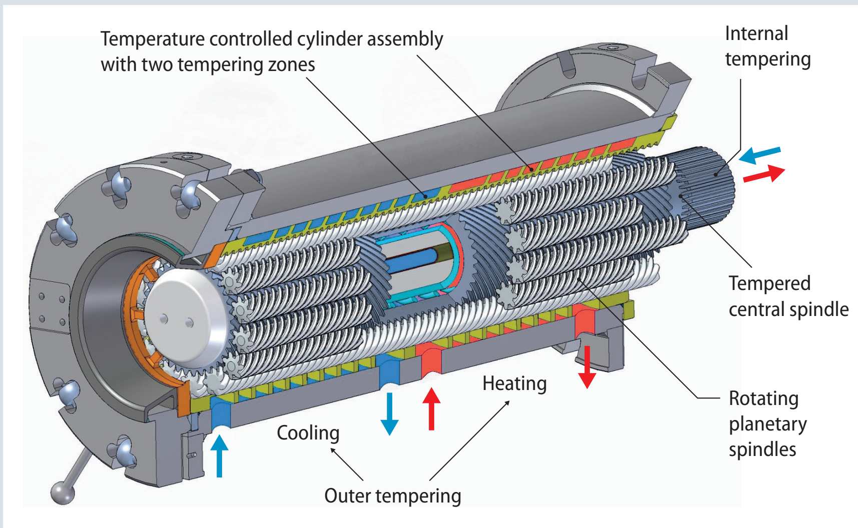

Fig. 1. Schematic view of a process module of the PRE: several planetary spindles rotate around the temperature-controlled central spindle in a temperature-controlled cylinder assembly Source: Entex; graphics: © Hanser

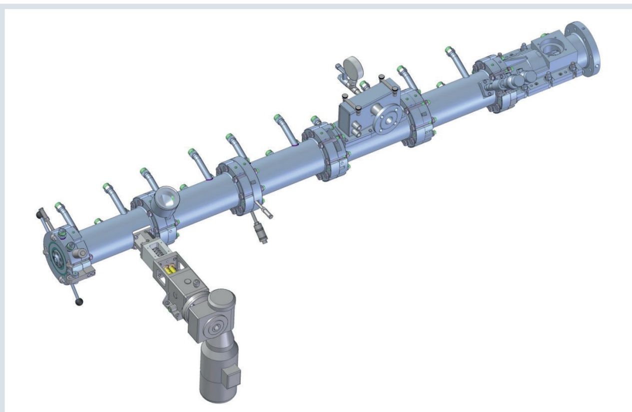

Fig. 2. With current PRE types, several process modules are connected in series. Moreover, additional systems for process improvement can be integrated © Entex

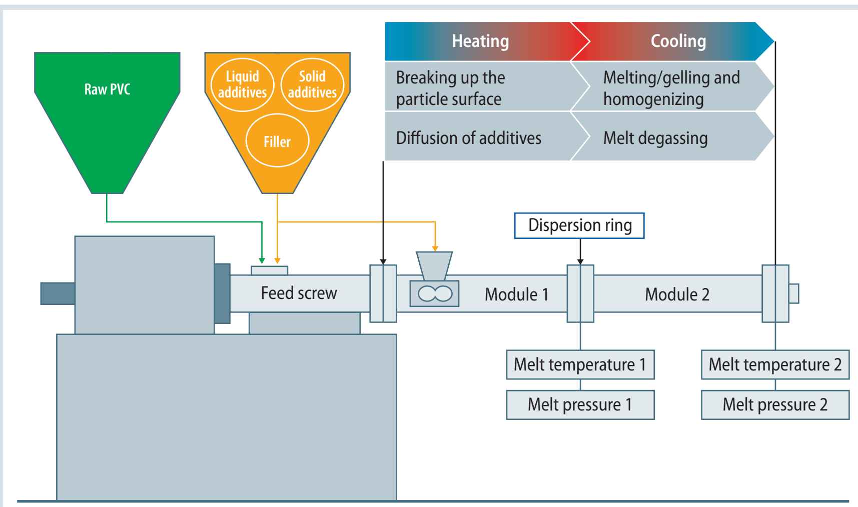

Fig. 3. The two-module PRE has already proven itself for soft PVC. A few adjustments were necessary for processing rigid PVC Source: Entex, SKZ; graphics: © Hanser

is the combination of a discontinuous process, the dry blend production, and a continuous process, the extrusion. For this reason, there is great potential for savings by simplifying the overall process. The research institute SKZ – Das Kunststoff-Zentrum and the planetary roller extruder manufacturer Entex Rust & Mitschke GmbH have therefore researched the potential for processing rigid PVC without prior dryblend production and developed a direct extrusion process in a joint project.

Potential Savings due to Planetary Roller Extruders

Planetary roller extruders (PRE) offer themselves as a machine type for exploiting this savings potential. PRE have long been used in PVC processing. At the beginning of the 1950s, the permanently increasing requirements in this area led to the development of this plant system that can process the PVC dry blend gently. The main idea in the development of this machine was to transfer the concept of the known discontinuously working mixing and rolling mills to a continuous machine. In the PRE, several planetary spindles rotate around the temperature-controlled central spindle in a cylinder that is also temperature-controlled (**Fig. 1**). In modern machines, several of such modules are connected in series. In addition, peripheral devices such as twin-screw side feeders, liquid injections and degassing systems can be integrated (**Fig. 2**). The modularity in combination with the large inner surface for temperature control of the material and the good mixing effect of the rotating planetary spindles make it possible to eliminate the dry blend production before the PVC extrusion when using a PRE [2, 3].

In a previous project, Entex has already examined the suitability of the PRE for the direct processing of soft PVC. A two-module system was used for this set-up and tested (**Fig. 3**). In the first module, the surface of the PVC grain is broken up by overrunning at moderate heat and thus the diffusion of the additives is made possible. Thereby, stabilizers and additives are mechanically pressed into the grain. This shortens the diffusion paths. The result is a quick effectiveness of the stabilizers. In addition, the initial degradation of PVC material is prevented by a precise temperature control.

Melting or gelling and homogenizing takes place in both modules. However, the first section of the extruder is crucial for this. The mechanical and thermal energy input must be carefully selected to prevent damage to the PVC, which is still inadequately stabilized. This requires the selection of a suitable planetary spindle configuration.

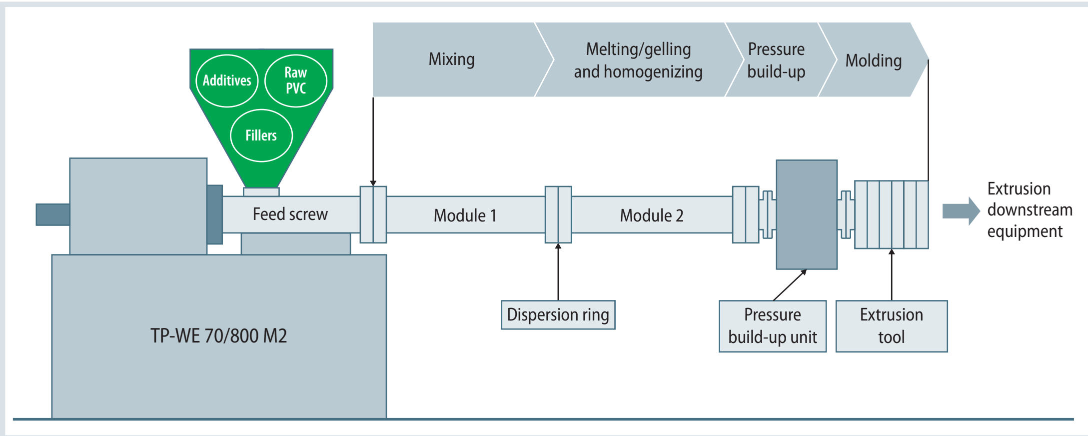

Fig. 4. Schematic view of the direct extrusion line for rigid PVC: a connected pressure build-up unit provides the pressure required for extrusion Source: SKZ; graphics: © Hanser

The type and number of planetary spindles affect both the mechanical energy input as well as dispersive and distributive mixing effects. The temperature profile also plays an important role, because between sufficient diffusion speed and thermal damage there is a fine line. Other important influencing factors are the speed and the diameter of the dispersion ring. In the second module it is also possible to degas the melt. The technology has already been successfully established for the granulation of soft PVC (PVC-P, plasticized) and calender feeding.

Challenges in Setting up the Direct Extrusion Line

Based on the successful implementation of the direct processing of soft PVC on the PRE, in the joint project with the SKZ it was examined whether the knowledge obtained can be transferred to rigid PVC (PVC-U, unplasticized). The aim of the project was to extrude rigid PVC directly on the PRE with constant heat and without prior dryblend production. The implementation of rigid PVC is much more complex than that of soft PVC. There is no softener in the formulation of rigid PVC, which is why pure solids are transported at the beginning. In addition, the temperature must be controlled even more precisely in the process than with soft PVC. At the same time, good dispersion of all components must be ensured in order to be able to guarantee the requirements for the mechanical properties. Furthermore, the pressures when processing rigid PVC are usually significantly higher than with soft PVC.

The two-module PRE set-up served as the basis for the direct extrusion line. Since the planetary roller extruder cannot build up enough pressure for profile extrusion, a pressure build-up unit suitable for rigid PVC had to be determined and tested (**Fig. 4**).

PVC Granulates as Alternatives to Dry Blends

The extent to which the PRE is suitable for the continuous processing of rigid PVC was examined at the beginning of the project. For this purpose, three PVC mixtures were prepared in different ways and tested. The first mixture was produced in accordance with the classic batch process using a HCM and was available as a dry blend. The second mixture (HCM + PRE) was also produced by means of a HCM and additionally granulated on the PRE. Regarding the third mixture (PRE), the individual components of the formulation were cold premixed (cold mixture) and processed and granulated on the PRE. A standard PVC formulation for window profiles that is customary at the SKZ was selected for the examinations. The three mixtures were then processed into profiles on a counter-rotating twin-screw extruder (DSE). Appropriate test specimens were taken from the extruded profiles and their thermal stability and mechanical properties were tested.

To check the PVC stability, inter alia the mean molar mass was determined by gel permeation chromatography. The mean molar mass of the three »

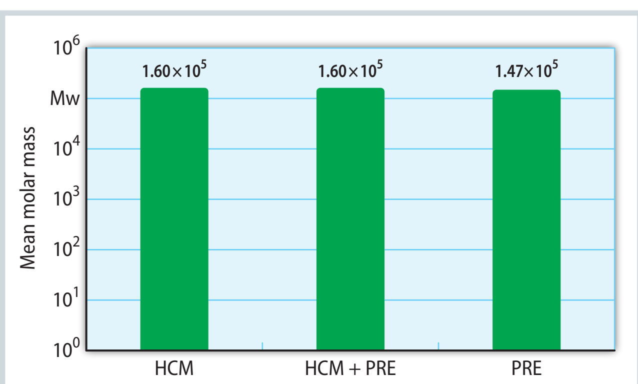

Fig. 5. Results of the gel permeation-chromatographic test with the two-module PRE set-up: the mean molar mass of the three samples is largely identical Source: SKZ; graphics: © Hanser

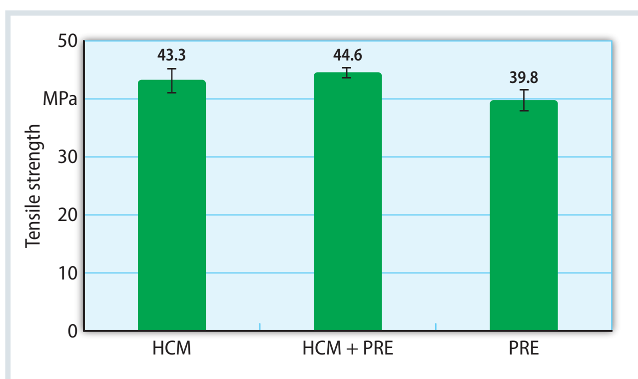

Fig. 6. The sample PRE has a slightly lower tensile strength than the samples processed in the other two processes Source: SKZ; graphics: © Hanser

samples was in each case at the same level (**Fig. 5**). Thus, there was no degradation of the polymer chains in any of the samples.

To assess the mechanical properties, tensile tests and the determination of the Charpy impact strength were carried out. The tensile strength of the PRE sample was slightly lower compared to the other two samples (**Fig. 6**). However, a significant decrease in the mechanical properties was found when determining the impact strength (**Fig. 7**). While the samples HCM and HCM + PRE were at the same level, the PRE sample showed a significant drop in impact strength. This is presumably due to an insufficient dispersion of the fillers. An expansion of the PRE to three modules can counteract this. This means that PVC granulates can be produced with this process without having to mix the material into a dry blend beforehand.

Which Pressure Build-up Unit Is Suitable?

When carrying out the strand granulation, a pressure of approx. 30 bar is necessary. This pressure could easily be built up with the PRE. Significantly higher pressures are required for the extrusion of semi-finished products. In order to use the PRE as a pure continuous processing mixer for the direct extrusion, this should be decoupled from the pressure build-up. Therefore, a pressure build-up unit is additionally required for processing in constant heat.

In principle, a gear pump, a single-screw extruder (ESE) or a short counter-rotating DSE could be used to build up pressure. After consultation with various gear pump manufacturers, these are not suitable for the direct extrusion of rigid PVC, because the risk of PVC degradation in the bearings is too high in permanent operation. Tests with a counter-rotating DSE available at the SKZ showed that a pressure-free transfer does not guarantee a sufficient feeding of the melt. A transfer via a melt pipe failed due to the pressure required to overcome the pipe. A direct flange-mounting of a counter-rotating extruder could not be realized in the project due to time and cost reasons. Even if this variant is interesting from a procedural point of view, the focus was therefore on the pressure build-up with an ESE.

The project partners opted for an ESE 120 from Entex with an L/D ratio (L = length of the flow channel, D = screw diameter) of 5.5, which is also used for pressure build-up during the extrusion of soft PVC or plastics filled with wood fibers. In contrast to conventional plastification extruders, this extruder fed with melt has a liquid temperature control, which ensures good melt temperature control.

A prototype line was set up in the technical center of Entex. In order to examine the pressure build-up, direct extrusion tests were carried out with a simple profile tool with a variable outlet geometry without calibration. Three different mixing scenarios were prepared for the direct extrusion. The first mix was the ready mix (warm mix), which was produced in the HCM. The second mixture was the mixture premixed without energy input (cold mixture). The third mixture was divided into three dosing feeders in order to reproduce the addition of individual components.

Successful Tests of the Prototype Line

The pressure build-up capacity of the different dies was examined by means of warm mixture. The highest pressure of approx. 180 bar could be built up with an oval die, the dimensions of which were 32 mm x 4 mm. With this die, it was possible to achieve a pressure that comes very close to a profile tool. In the next step, the cold mixture was tested on the line. At the same throughput, the PVC cold mixture was after both the PRE and ESE as just homogeneous as in the reference test with the warm mixture. A

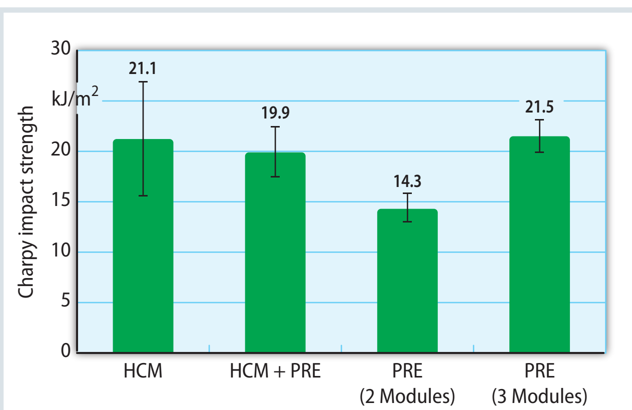

Fig. 7. In the tests of the Charpy impact strength, the sample processed in the PRE fell significantly below the other two. However, if three modules are used instead of two, it even achieves better values Source: SKZ; graphics: © Hanser

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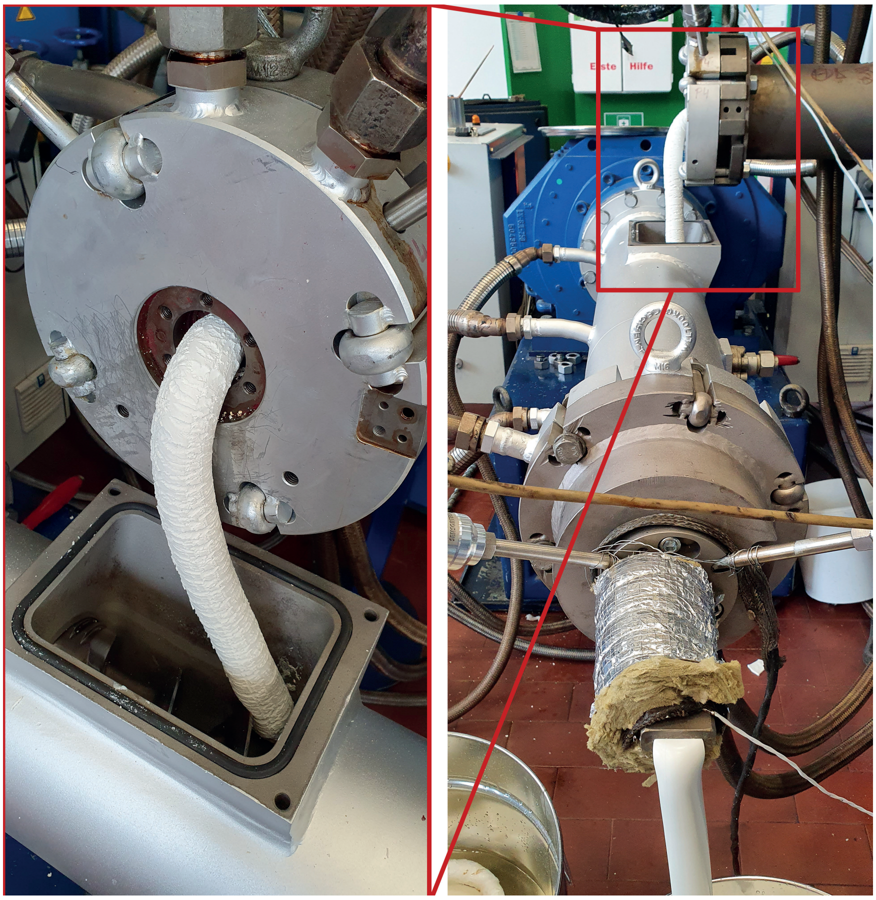

Fig. 8. With the installed line, a direct extrusion of rigid PVC using planetary roller extruders is possible © SKZ

pressure of approx. 180 bar could also be built up in this test. Finally, the test was carried out with single components as direct extrusion. In this test, too, a homogeneous PVC mixture could be realized with the same throughput (**Fig. 8**). This made it possible to achieve a pressure of approx. 170 bar. The results show that the PRE is very well suited for PVC processing without prior dryblend production allowing to skip the HCMs and thus reducing production costs. The tests demonstrate that a suitable pressure build-up device can be used for a direct extrusion of PVC.

With this process, Entex and the SKZ have developed an option for continuous PVC granulate production without prior dryblend production. Compounds produced in the process have mechanical and thermal properties comparable to those of a discontinuously produced dry blend. Furthermore, a prototype plant for PVC direct extrusion was successfully set up and tested in the Entex technical center. The results of the conceptual work will be used in the future to implement a direct extrusion line for the production of rigid PVC profiles. ■

Film Skiving Machine

High-Precision Skiving of Ultra-Thin PTFE Films

The ever-increasing demand for high-tech products ensures a worldwide increase in demand for high-precision films made of PTFE. The film skiving machine **Keller HCW GmbH**, Ibbenbüren, Germany, is used in areas where high standards are set on the skived films, such as in medical technology, the automotive industry, solar technology and especially in communication technology for high-frequency lines and high-frequency antennas. Here, extremely thin films are required in compliance with the specified tight tolerances.

The film skiving machines enable the skiving of ultra-thin films from 20 µm with a thickness tolerance of ±3 µm, with skiving billet diameters of up to 800 mm and skiving billet lengths of up to 1600 mm © Keller HCW

In order to meet these requirements, special importance was attached to the rigidity of the machine during design. The rigidity allows an almost vibration-free skiving process. This ensures the skiving of ultra-thin films from 20 µm with a thickness tolerance of ±3 µm, with skiving billet diameters of up to 800 mm and skiving billet lengths of up to 1600 mm.

According to the company, the use of this film skiving machine requires simple operation, but at the highest level of control technology. All functions required for the operation of the machine can be set with the main operating unit. Further operating units for support are available.

The scope of delivery of the skiving machine is completed by components for specific requirements, such as a winding-up device for skived films, a knife grinding device for resharpening the high-performance knives, and a mandrel winding-up device for pressing the mandrel into the hollow plastic cylinder.

To the product presentation:
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