Leistritz Extrusion Technology

At Your Service. Globally.

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Leistritz
EXTRUSION TECHNOLOGY

COMPOUNDING

Extruders and extrusion lines

COMPOUNDING.

HIGH THROUGHPUTS IN THE BEST QUALITY

Focus on material characteristics

Compounding is a process in which the polymer is melted and mixed with e.g. additives, fillers or reinforcing materials. This process changes the physical, thermal, electrical or aesthetic properties (conductivity, flame resistance, wear resistance, color etc.) of the polymer. The final product is called a compound.

Compounding, in other words the processing of plastics, is one of the prime disciplines of *Leistritz* twin screw extruders. Diverse incorporation options for filler and reinforcement materials into the polymer matrix are possible and lead to new material properties, which are used in a multitude of applications.

Typical Compounding tasks include:

- reinforcing polymers, e.g. by incorporating glass, carbon or natural fibers
- improving the dimensional stability and breaking strength of polymers, e.g. by incorporating inorganic fillers, glass beads
- improving the flow behavior and flame resistance of polymers, e.g. by incorporating low-viscosity substances or flame retardants
- the manufacture of polymer blends, e.g. by mixing compatible or incompatible polymers (impact-resistant modification of thermoplastic materials)
- enhancing the chemical/physical durability of polymers, e.g. by incorporating stabilizers, anti-static agents

Compounding
means satisfying the requirements specification of the end product in an ideal way.

Basis: raw polymer

- Filling (e.g. $CaCO_3$, wood compounds, talcum)
- Reinforcing (e.g. glass or carbon fibers)
- Additivation (e.g. flame retardants, UV stabilizers)
- Cross-linking of elastomers (e.g. TPE-V)
- Reactive extrusion
- Blending (e.g. PC + ABS)

INCORPORATING FILLERS.

It's all about good dispersion

Fillers are added to polymers to improve their properties and/or reduce the price of the compound. The good incorporation options for fillers in the polymer matrix are used in a wide variety of applications, such as the manufacture of computer cases. Another example: drain pipes. The filler is used here as sound insulation so that flushing noises cannot be heard in apartment buildings, for example. *Leistritz* extruders are able to incorporate a very high share of fillers, for example in the filler masterbatch.

The polymer can be mixed with up to 85% of fillers such as chalk or talcum. Side feeders are used to incorporate fillers (see p. 14). Two or more may be used for larger shares of fillers. The modular extruder is simply extended in such cases. The volume flow of the added materials is distributed amongst the existing feed options - depending on the formulation - to minimize abrasion and to wet the filler as well as possible.

The main demand on the extruder is to incorporate large quantities of the filler. The primary task is to disperse the filler optimally and distribute it in the polymer matrix.

The dispersion process can be split into the following steps:

- melting of the polymer matrix
- wetting the filler with the melt
- dispersion of agglomerates and aggregates (dispersive mixing)
- homogeneous distribution in the matrix (distributive mixing)
- homogenization and degassing of the melt

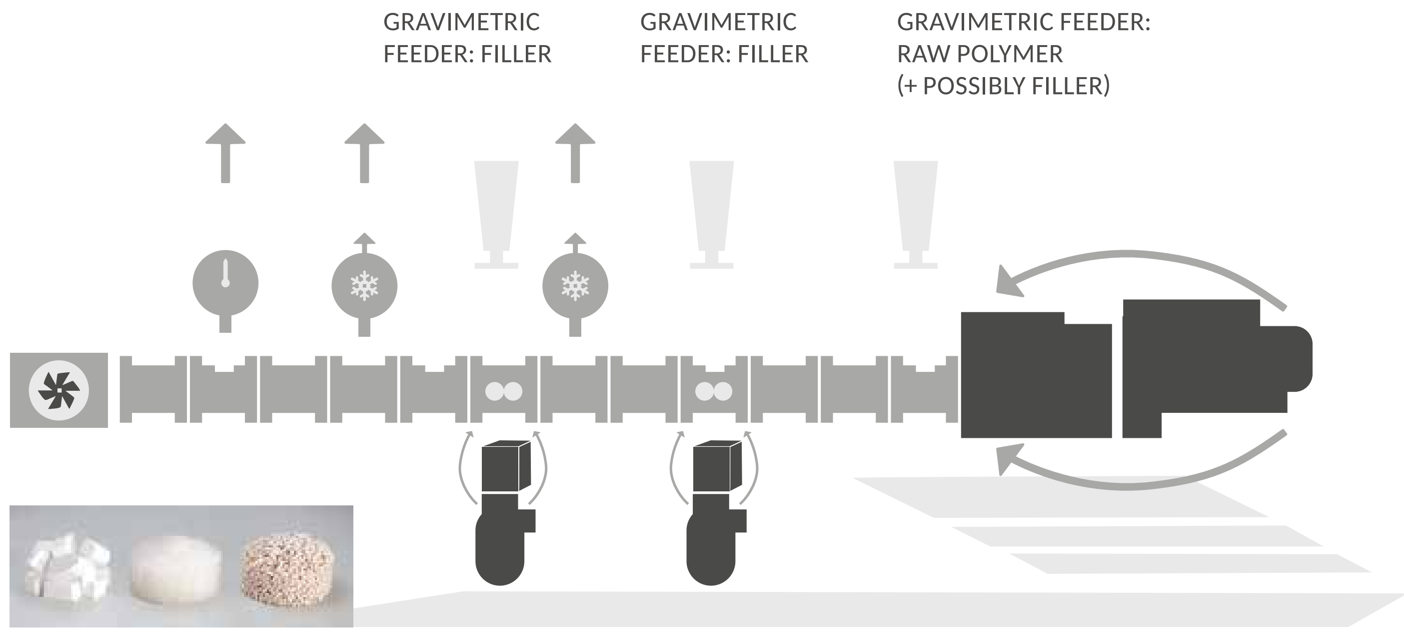
Frequently used inorganic fillers

- **Talcum** is flaky; is preferably added to the melt via a side feeder; gives the final product special surface properties
- **Calcium carbonate ($CaCO_3$)** is cubic; available in three states: chalk, limestone and marble; cost-efficient
- **Barium sulfate ($BaSO_4$)** are rhombic crystals (cuboid); added via a side feeder, has a high specific weight and density
- **Wollastonite** is fibrous: added via the side feeder

Example of a compounding plant to incorporate calcium carbonate (further details on p. 10/11)

Example of a formulation: 70 - 80% $CaCO_3$ + 18 - 30% polyolefins + 0 - 2% additives

Line layout:



Filler criteria

Fillers are incorporated in plastics to improve the material characteristics of the compound and/or to save costs. There are three important criteria that affect the interaction between the filler and the polymer matrix:

- **Particle shape** of the filler
  Particles with a small aspect ratio (e.g. glass beads, $CaCO_3$ or $BaSO_4$) do not significantly improve the tensile strength and tear resistance, but do normally improve the modulus of elasticity. Particles with a large aspect ratio (e.g. talcum or wollastonite) help improve the tensile strength and tear resistance as well as the modulus of elasticity.
- **Particle size distribution** of the filler
  The behavior of filler particles during processing depends on both the Van-der-Wals forces acting between the particles (with particle sizes > 1 µm) and the dispersive shearing forces in the extruder (with particle sizes < 10 µm).
- **Surface** of the filler
  The specifi c surface (m²/g) indicates the number of adhesion points between the filler and polymer chains: large surface > numerous adhesion points > better mechanical properties (higher stiffness and surface gloss of the polymer, better tensile strength and tear resistance as well as impact strength). The surface coating is also important because it changes the surface energy: a hydrophilic surface becomes hydrophobic. This hydrophobing means that fewer agglomerates form and the free-flowing property is improved. The wetting is essentially affected by how far apart the surface energies of the particles and the polymer matrix are. The closer together they are, the better the wetting.

REINFORCING COMPOUNDS.

Break resistant and stiff

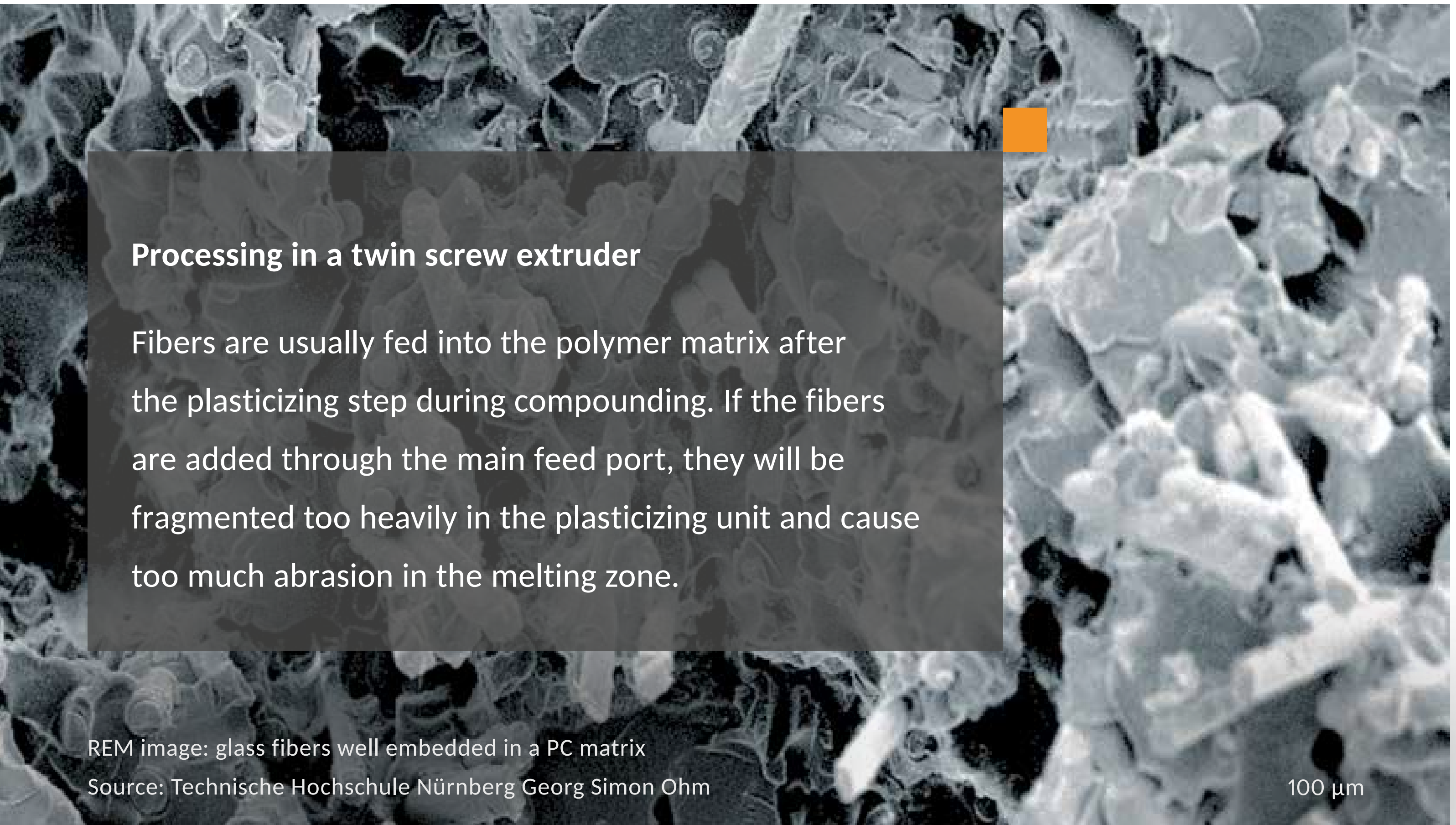
Particularly for applications requiring properties such as strength and stiffness, the polymer (e.g. PP or PA) is reinforced with materials such as glass fibers, carbon fibers, and also natural fibers. The filler content of PP with glass fibers, for example, can be up to 60% depending on the application.

The addition and combination of the polymer chains to and with the fiber structures creates a very strong bond that matches, and sometimes even exceeds the properties of metallic materials. Their low weight make reinforced thermoplastic materials a very popular material, particularly in automobile manufacturing.

Example: glass fibers

The goal of processing glass fibers in a twin screw extruder is to distribute the fibers homogeneously in the polymer matrix and achieve an optimum length distribution in the final product with the lowest possible destruction of the fibers. The size on the fibers makes them smoother and more resistant to mechanical loads. However, the size has to be compatible with the polymer matrix. Chopped or short glass fibers with initial fiber lengths of approx. 3 mm are usually used. Alternatively, rovings (filaments) may also be added.

long fiber lengths	→	better mechanical product properties, poorer flow behavior in the melt (e.g. during further processing in injection molding)
short fiber lengths	→	poorer mechanical product properties, better mold-filling behavior during injection molding



Processing in a twin screw extruder

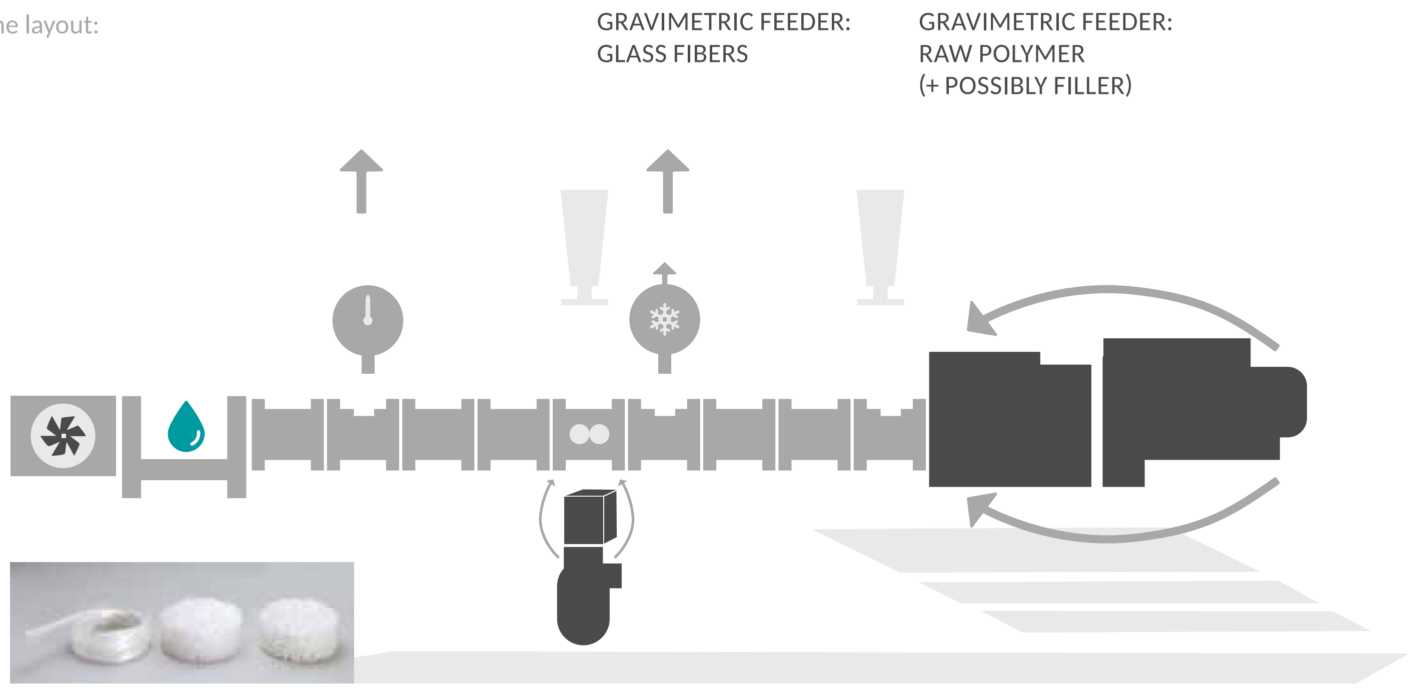
Fibers are usually fed into the polymer matrix after the plasticizing step during compounding. If the fibers are added through the main feed port, they will be fragmented too heavily in the plasticizing unit and cause too much abrasion in the melting zone.

REM image: glass fibers well embedded in a PC matrix
Source: Technische Hochschule Nürnberg Georg Simon Ohm

100 µm

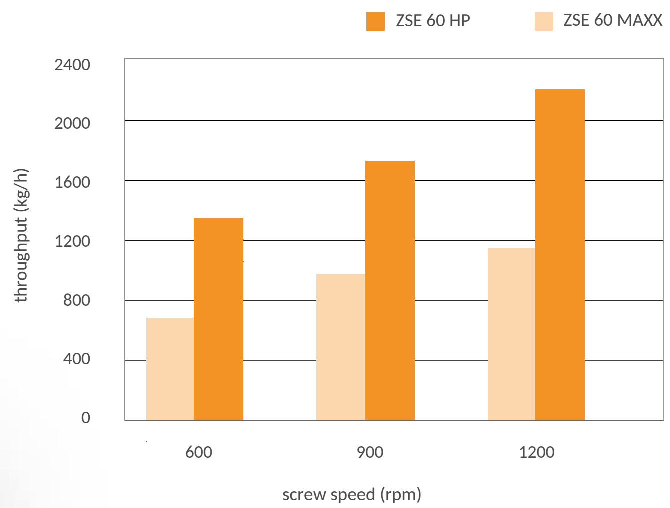
Application example: incorporation of glass fibers (30%) into polycarbonate (70%)

Line layout:



Test: ZSE MAXX (Da/Di = 1.66) v. ZSE HP (Da/Di = 1.5)

PA + 30% GF



Results:

- A ZSE MAXX extruder is the right choice for running shear-sensitive applications.
- Up to 55% more throughput can be realized here.
- When working with higher filling degrees energy savings of up to 15% are possible due to a higher volume and high torque.

THERMOPLASTIC ELASTOMERS.

Elastic, pliable, flexible

Thermoplastic elastomers (TPE) are materials in which elastic polymer chains are incorporated in a thermoplastic material. They can be processed in a purely physical process through the use of high shearing forces, exposure to heat and subsequent cooling. They can be melted and shaped by heating again.

A number of TPEs exist that differ greatly in both their polymer structures and their properties. Their common feature is the basic structure in the form of block polymers in which the elastomer segments copolymerize with the basic polymer. The share of elastomer chains in the overall polymer can be varied broadly for a number of TPE classes. This means that settings from very stiff to almost gel-like are possible.

TPEs are used in a wide variety of industries: in the automotive sector, for example, they are used as window surrounds or control elements. They are also used in industry for tool handles or sealing rings, for example. Or in the consumer sector for toothbrushes or packaging.

The production of numerous different thermoplastic elastomers calls for a profound knowledge of machines and process engineering. Depending on the type of elastomer (from a standard SEBS through to dynamically cross-linked TPE-V systems) various machines concepts are applied. What is important is the necessary process engineering know-how and flexible extruders. The process lengths of the twin screw extruders used here range from 48 L/D up to 68 L/D. The addition of oil, fillers or various cross-linking agents varies depending on the application.

Knowing which machine concept is to be used calls for the necessary process engineering know-how.

Application example: TPE-V
TPE-V is the name given to thermoplastic elastomers with a cross-linked rubber component. Very long process lengths of up to 68 L/D are used in the production of TPE-V. This means that the necessary residence time and respective process steps (blending the EPDM with the polymer matrix, mixing in of additives, dynamic cross-linking) can be generated. The design of such a plant relies on the wealth of experience of our process engineers who set up the processing unit to match the individual process steps.

POLYMER BLENDS.

Cost efficient and performance-optimized

Blends off er the possibility of creating a whole series of new, more efficient and less expensive polymers with customized properties from the available potential of basic polymers. Their main field of use is in the automotive and electrical industry. They are found here in shock absorbers or hub caps as well as the casing material for telephones and computers.

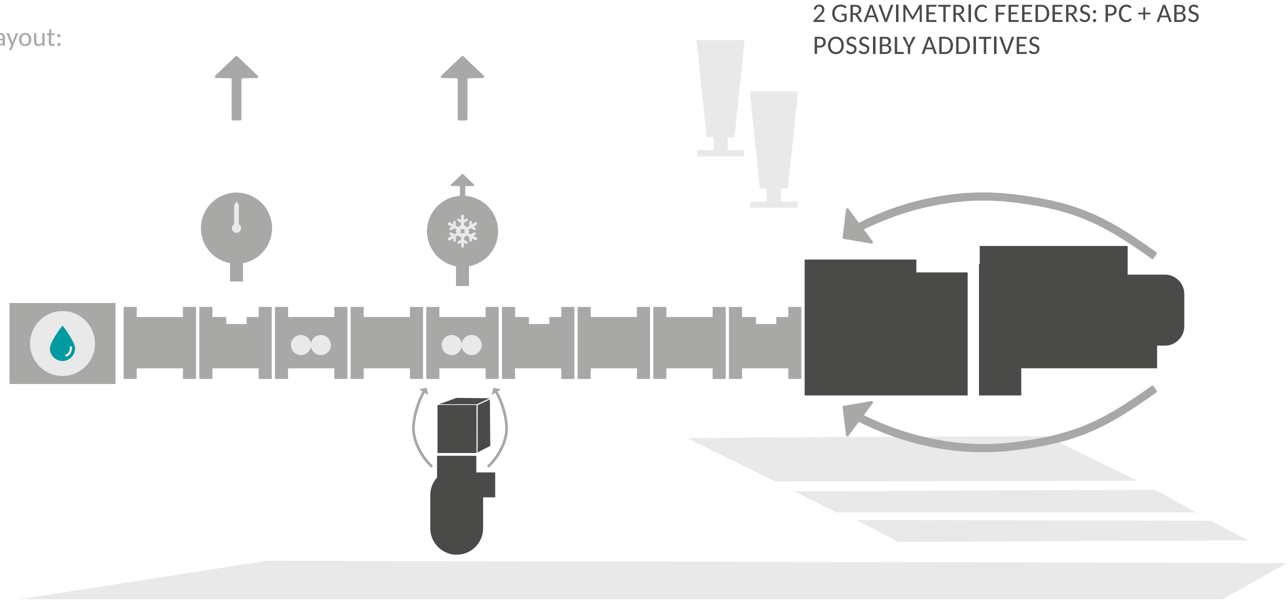
The compatibility of the basic polymer is crucial and plays an important role for the compounding.

There are three groups:

- blends with full compatibility between the basic polymers (e.g. SMA + SAN, PPO + HIPS)
- partially compatible blends: basic polymers form a two-phase matrix, but with good physical interaction (e.g. PC + ABS, PC + PBT)
- blends with incompatible basic polymers (e.g. PA + ABS, PPO + PA)

Application example: PC + ABS blend

Line layout:



This polymer blend combines the advantages of polycarbonate (PC) and acrylonitrile butadiene styrene (ABS). It is one of the few blends that achieves a synergistic effect alongside the mere benefits of the basic polymers: the resulting material has properties that none of the basic polymers have. For example, the low-temperature impact strength of the blend is far superior to that of either of the basic polymers. PC gives the blend a high tenacity at room temperature and heat deformation temperature, ABS a good resistance to stress cracks and processibility. However, the blend also has an exceptional impact strength, even at an ambient temperature of -30 °C.

An important process engineering aspect that has to be taken into account here is that the two different polymers also have different viscosities in the melt. Therefore, the choice of the accurate screw geometry is crucial. A good morphology can only be achieved with an adequately designed setup.

EXTRUSION LINE FOR HIGHLY FILLED COMPOUNDS.

High engineering competence

High-tech compounding plant for highly filled compounds

Task:

design and construction of a plant for the stable and largely automated production of highly filled compounds of a constant product quality.

Plant concept:

- material supply from sacks, big bags and silos
- formulation-controlled suction system for premixes
- gravimetric feeding system
- twin screw extruder ZSE 75 MAXX
- gear pump and screen changer
- underwater pelletizing
- filling station
- control system + control panel

Process engineering concept:

The art of producing highly filled compounds lies in the optimum distribution of the material streams. Great process engineering expertise is required to incorporate large quantities of fillers in the most homogeneous way in a polymer matrix. The air streams brought in with the material feeding in particular have to be controlled. A further challenge is posed by the material moisture, which may complicate the process. Accordingly, the processing unit and screw geometry must have an optimum configuration for this task.

This plant example convinces through state-of-the-art technology. The high volume (OD/ID = 1.66) and the high specific torque of up to 15 Nm/cm³ of the ZSE 75 MAXX twin screw extruder means that not only can maximum throughputs be run, but an energy-efficient production can also be realized. The topic of flexibility is also taken seriously: whereas the plant was built to produce highly filled compounds with up to 85% calcium carbonate, various other processes can also be run on it with minimum adjustments, for instance talcum, titanium dioxide or barium sulfate. Aluminum or magnesium hydroxide can also be processed for the field of flame retardancy.

LARGE-SCALE COMPOUNDING FOR PP STABILIZATION.

Competent system supplier

Task:
design, planning and construction of a large-scale compounding plant (climate zone from -40 – +40 °C).

Plant concept:
- material supply in a nitrogen atmosphere from a reactor
- mixing and supply silos
- dosing units
- extrusion line with a ZSE 180 MAXX twin screw extruder
- gear pump and screen changer
- underwater pelletizing
- homogenizing silos
- bagging station with subsequent palletless palletizing
- control with integrated online rheometer

Self-controlled adjustment of the MFI value

Panorama view of the overall plant

Process engineering concept:

PP is produced in the upstream polymerization plant. The raw polymer powder from the reactor is transported in a nitrogen atmosphere over a distance of approx. 350 m to the co-rotating twin screw extruder ZSE 180 MAXX where it is stabilized against auto-oxidation (throughput 10 t/h). The specific adjustability and uniform viscosity of the stabilized polypropylene during the extrusion process plays a crucial role in terms of process engineering. This viscosity is measured during the process with an online rheometer. By using a special controller integrated in the *Leistritz* control unit, metering of the peroxide masterbatch and thus the viscosity (MFR/MFI) is adjusted to the specifications and any fluctuations in the raw polymer can be compensated.

SIDE FEEDING.

Easy material feed - modular adjustment

The side feeder is mostly used to add powders. *Leistritz* can off er the right side feeder for every application and all extruder sizes. The LSB XX series convinces through the high OD/ID ratio (2.0) of the screws and can also convey materials with very low bulk densities.

Special features of the LSB XX:

- segmented screws can be used (configuration according to the needs of the raw material)
- adaption of the LSB XX to the extruder with tie rods (LSB XX can be fastened to the extruder barrel in the cold, easily accessible area of the gear box with no risk of injuries)
- use of various types of steel (allows feeding both highly abrasive (e.g. TiO_2) and highly corrosive products)
- option: internal cooling of the screw (possible through special gear box design)

LSE XX (lateral attachment)

Technical specifications: LSB XX

LSB XX	27	35	40	50	60	75	87	110	135
Extruder size	ZSE 27 MAXX	ZSE 35 MAXX	ZSE 40 MAXX	ZSE 50 MAXX	ZSE 60 MAXX	ZSE 75 MAXX	ZSE 87 MAXX	ZSE 110 MAXX	ZSE 135 MAXX
Screw diameter (mm)	27,5	34,4	40,8	49,5	60,3	75,9	88,4	112,3	138,1
Screw speed infinitely variable (rpm)	0-600							0-450	
Drive power (kW)	0,8	1,5	2,4	3,8	5,3	9,1	14,3	18,6	35,3
Base frame	without		with						

SIDE DEGASSING.

Reliable degassing of volatile substances

Apart from the generally known process tasks such as melting, mixing or homogenizing, the degassing of volatile substances is a key part of plastics processing. *Leistritz* can off er the perfect side degasser for every application and all extruder sizes. As an alternative to conventional passive degassing systems, there are the *Leistritz* side degassing LSE XX and the *Leistritz* vertical degassing LVE XX. They allow a safe degassing of the extrusion process, even in unfavorable process conditions such as during start-up or heavily foaming products.

In connection with the largest possible free volume in the screw flight of the extruder and the constant renewal of the product surface, it creates optimum conditions for degassing the polymer molten mass. The two screws that rotate in the same direction that are fitted in the side degassing force any melt that tries to escape back into the process chamber but allow all gases to pass. This avoids any blockages or deposits in the degassing barrel. The productivity and safety of extrusion plants are increased in this way.

Technical specifications: LSE XX

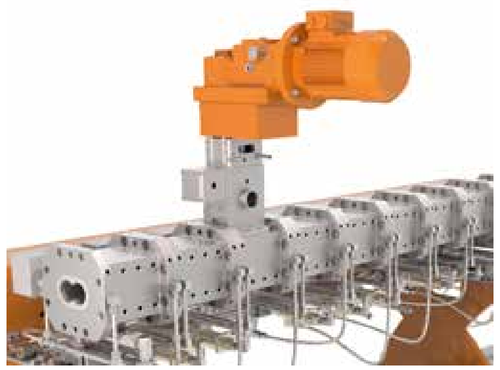
LSE XX	27	35	40	50	60	75	87	110	135
Screw diameter (mm)	27,5	34,4	40,8	49,5	60,3	75,9	88,4	112,3	138,1
Extruder size ZSE	27 / 35	40	50	60	75	87	110	135	160 / 180
HP	✓ ✓	✓	✓	✓	✓	✓	✓	✓	
MAXX	✓	✓	✓	✓	✓	✓	✓	✓	✓ ✓

Technical specifications: LVE XX

LVE XX	27	35	40	50	60	75	87	110	135
Extruder size ZSE	27 / 35	40	50	60	75	87	110	135	160 / 180
HP	✓ ✓	✓	✓	✓	✓	✓	✓	✓	
MAXX	✓	✓	✓	✓	✓	✓	✓	✓	✓ ✓

Special features:

- OD/ID = 2 (higher free volume)
- LSE barrel heated by heating cartridges
- cooled gear box lantern (prevents overheating of the gear box)
- horizontal (lateral) attachment on the base frame or vertical via special adapter (barrel insert)



LVE XX (vertical attachment)