NCT extruders process PET as recyclate, produce WPC and compound various starting materials to produce profiles, pipes or plates (photos: M-A-S)

Conical Co-Rotation

Extruder Technology. A co-rotating twin-screw extruder with conical design is even capable of processing those materials which have low bulk densities, such as chopped film, PET flakes and WPC. The extruded material is of superior quality because of gentle plastication, improved homogenization and highly stable melt pressure.

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New conical Technology (NCT) is a polymer extrusion technique with conical co-rotating twin screw. M-A-S Maschinen-und Anlagenbau Schulz GmbH, Pucking, Austria, launched it at K 2007 two years ago. Since then, the technique has become successfully established for the recycling of polyethylene terephthalate (PET), the production of highly filled plastics (WPC) and the compounding of various starting materials (**Title picture**). The NCT extruder combines two plastics processing systems, namely a co-rotating twin-screw extruder and a conical counter-rotating twin-screw (**Fig. 1**). Available in five different sizes, the extruder series covers an output range from 50 kg/h to 1,800 kg/h.

Designs Compared

Modern extruder systems can be divided into closely intermeshing co-rotating extruders of cylindrical design and cylindrical or conical counter-rotators. Co-rotating twin-screw extruders are characterized by their very high mixing efficiency and good self-cleaning. Counter-rotating extruders work on the principle of chamber conveying, as a result of which substantial pump efficiencies are obtained. Mixing is not as good, however [1, 2].

Both options have advantages and disadvantages. The extrusion process, therefore – depending on the polymer used – is always a compromise. The extruder which M-A-S has developed boasts the processing advantages of a parallel co-rotating machine, while its conical design is capable of accommodating significantly higher pressures and moments. In particular, the large screw diameter in the feed zone and the large axial spacing between the two screw shafts are of advantage during extrusion [2]. The main characteristics of the different screw systems are compared in the **Table**.

A New Screw Design

The heart of any extruder is the plasticizing unit. This series has a screw system with six zones (**Fig. 2**). The feed zone is mostly filled by gravimetric feeders. It has a relatively large chamber volume for optimum filling of the screws. In general, the machine is always under-charged by the feeder. The melting zone is completely filled by the backup from the flow-restriction zone. Due to the large surface area of the screw, the necessary melting energy is introduced into the material very well. The flight volume of the flow restrictors with reduced pitch essentially determines the plasticizing action of the screws.

Screw elements, such as flow restrictors or shearing and mixing elements can be exchanged. The modular design allows the plasticizing unit to be customized to requirements. Mixing and kneading elements are used to homogenize the melt. An integrated degassing zone also permits

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Fig. 1. The developed extruder combines two proven designs, the co-rotator and conical, into a new system

wet polymers to be processed. The downstream discharge zone is responsible for building up the pressure. The very high overlap of the closely-meshing screws creates a high buildup of pressure, combined with constantly high output, and very high venting performance.

In parallel twin screw extruders, the maximum transferable torque decreases with increasing flight depth, while on the other hand, the free volume increases. The conical design uncouples the geometric relationship between diameter and axial spacing and maximum transferable torque. This makes it possible to transfer a significantly higher torque despite a large free volume. The torque of conical designs is roughly four times the torque of parallel, co-rotating extruders.

Enhanced Performance

The large designs, e.g. the NCT90, also feature double venting. This means that the polymer is gently melted in two plasticizing stages. In each of the downstream venting zones, volatile components such as water or printing ink are extracted. The condensate is liquefied in two completely independent vacuum systems. The plasticizing unit was modified during scale-up to yield a disproportionate increase in surface area of the screw flanks. Plasticizing performance and processing bandwidth were thus significantly increased. The cylinder only needs a 24 mm axial traverse for swiveling the entire processing unit. This greatly simplifies screw replacement and maintenance.

The rugged design facilitates a drive output of up to 315 kW, which translates to torque of 9,400 Nm per screw shaft at a screw speed of 160 rpm. The specific energy consumption of 0.22 kW/kg, too, as measured during the manufacture of pellets from polypropylene film, is comparatively low. A closed, compact design protects all ancillary components from contamination and ensures a minimum footprint. For light materials, especially chopped PE film, with a bulk density of <100 g/l, a twin-screw stuffing device provides stable charging. As the gravimetric dosing unit can be custom arranged, it is always possible to process the right formulation **(Fig. 3)**. The largest extruder in this series can extrude up to 1,800 kg/h of preheated PET, up to 1,200 kg/h of polyethylene (PE) and polypropylene (PP), and up to 600/h of WPC profiles. The smaller version (the "55" model) delivers roughly half that performance.

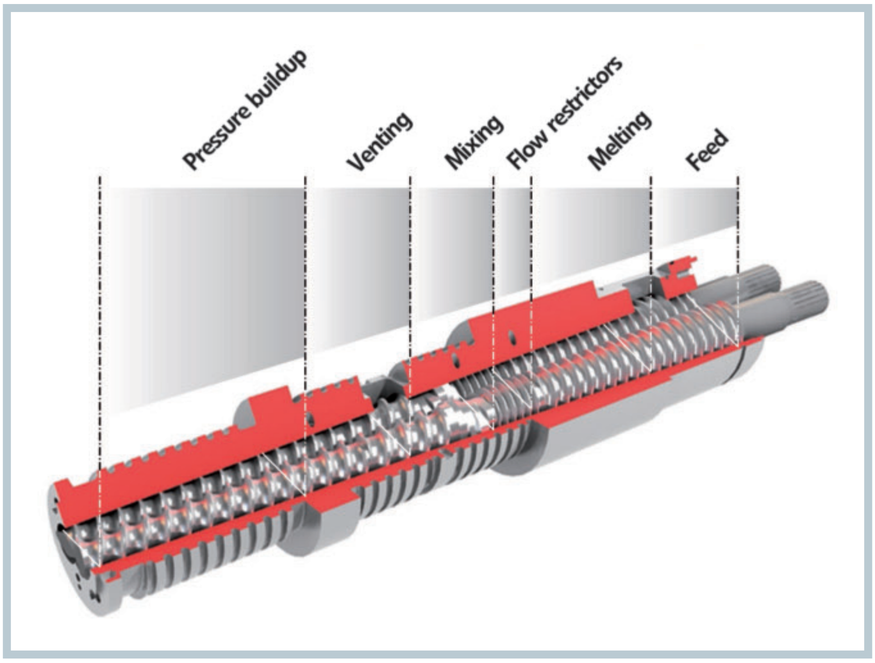

Fig. 2. The screw system is modular and has six different zones

Applications in Detail

For compounding PET, a high specific material throughput and high quality are required. Conventional systems have good output, however, but have shortcomings in mixing ability. The conical co-rotating machine achieves a high throughput with very good mixing, with the result that the final products have homogeneous, reproducible properties.

The series is ideal for processing PET-A (bottle regrind) and PET-G (film regrind). Moreover, it lends itself to regrinding and direct extrusion. Thus, a →

Property	Single screw	Twin screw, parallel co-rotating	Twin screw conical counter-rotating	Twin screw conical co-rotating NCT
Feed volume	++	+	+++	+++
Dwell time	+	++	+++	++
Length	++	+	+++	+++
Maintenance friendly	++	+	+++	+++
Mixing properties	+	+++	+	+++
Pressure buildup	+	+	+++	++

Table. Different screw systems are compared for their quality: + = adequate for the job in hand; ++ = good, eleveated requirements relative to the property; +++ = very good, relative to the even higher requirement

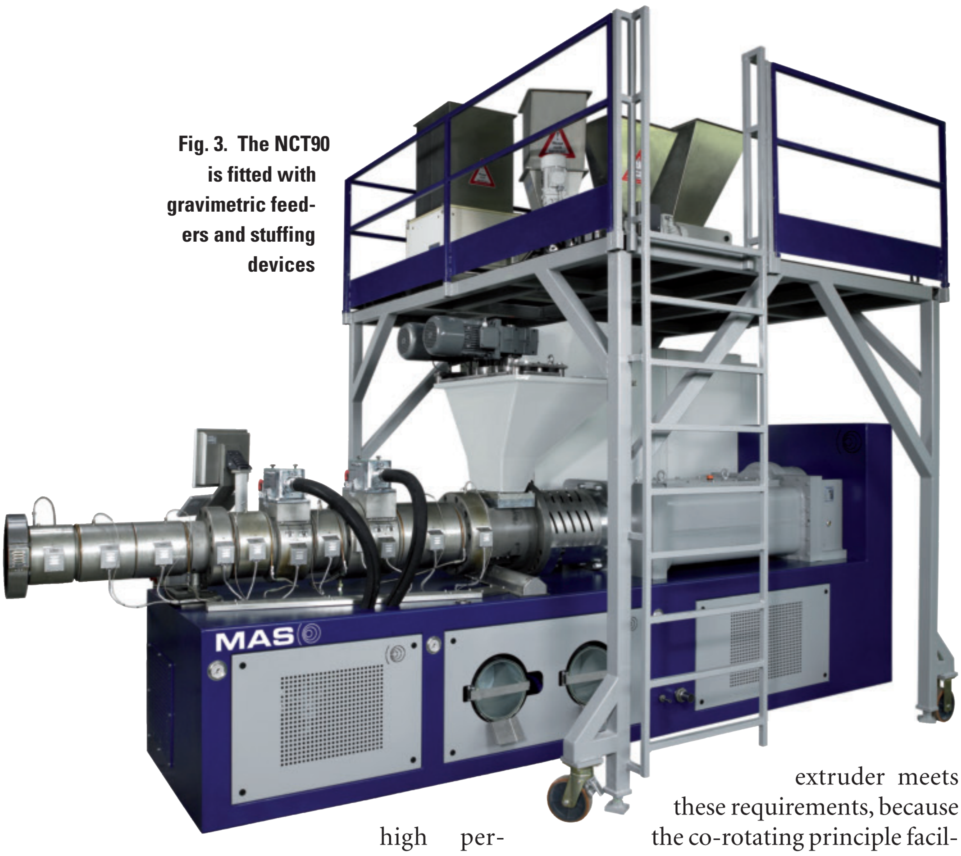

Fig. 3. The NCT90 is fitted with gravimetric feeders and stuffing devices

high percentage of the regrind generated in a company can be returned to film production. Thermoformed film produced in this way can be processed without further ado and yields very good color values and IV values (intrinsic viscosity as a comparative measure for the molecular weight). Considerable success has also been achieved in the recycling of PET bottles, too. For example, IV degradation, given appropriate pretreatment, can be kept to less than two points; this means that the regrind can be further processed with virtually no restriction.

In the processing of WPC materials, the moisture of the raw material (wood-plastic composite) is very important. The extruder must first homogenize the melt and then vent it. The conical co-rotating extruder meets these requirements, because the co-rotating principle facilitates very good dispersion. Fiber materials are digested (separated or refined), so that sufficient energy is introduced to release the water [3]. The large surface area in the venting zone ensures that WPC mixtures with up to 4 % moisture content can be properly vented. The extrudate has a density of 1.2 kg/dm^3.

Higher extruder speeds of up to 250 rpm favor fiber digestion, with the conical design ensuring constant output. This can be readily seen in the tensile specimens made from paper/fiber composite **(Fig. 4)**. Since the fiber is incorporated better into the polymer matrix, the polymer content can be reduced and the mechanical properties improved. The throughput rates achieved so far with the middle extruder are 350 kg/h for a wood/PP formulation for profiles, and 400 kg/h for pellets.

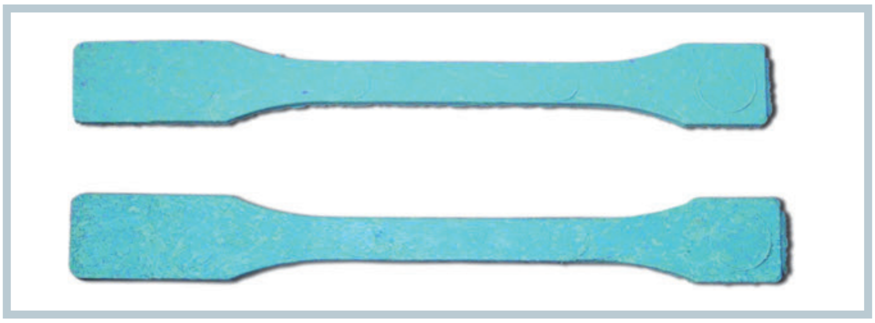

Fig. 4. Tensile specimens made from paper/plastic composite are compared for their homogeneity: NCT extruder (top) and counter-rotator (bottom)

Recycling and Compounding

There is a discernible change occurring in the recycling of plastics. Until now, plastics were reground so that a proportion of 10 to 100 % could be used again in a further processing step. Now, though, waste plastics are increasingly being treated with additives such as colorants and fillers, so that they can be processed to higher-value applications. In addition, the polymer should be processed directly to the semifinished product (profile, tube or plate) in just one processing step.

Since the conical co-rotating design leads to demonstrably very good homogenization, this property can be used for compounding processes, especially where different starting materials (regrind, flakes, chips, glass fibers, natural fibers, etc.) or additives with different material properties are to be mixed. Mostly, the recycled materials (recyclables) to be processed are crushed and have a very low bulk density. This is where the conicity comes into its own, as the large diameter screw feeder allows very high feed volumes. Thus, lightweight materials can be fed into the machine and processed. This is a crucial advantage, especially in the compounding of new and high-quality pellets, which will play a large role in everyday life in the future. ■

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