Fig. 1. Staple fibers for use in hygiene articles (figures: Gneuss)

PET Fibers. Application of the right machine technology allows the two trends towards a growing demand for technical fibers and an increasing use of recycled material to be served simultaneously. By modifying the extrusion line from a single-screw extruder to a MRS extruder, for example, one manufacturer was able to increase throughput by more than one-third, to improve the quality of the fibers and to reduce energy costs.

Serving the Growth Market for Staple Fibers Ecologically

AXEL HANNEMANN

While some 35 million tonnes of natural and man-made fibers were produced worldwide in 1985, the figure had far more than doubled to around 80 million tonnes in 2010 [1]. After the steady growth, 2010 was a special year for the world textile industry – with 8.6 % the fibers recorded the strongest growth in the last 25 years. A pro capita consumption of roughly 12 kg was achieved [2]. The experts attribute this enormous increase to the consumers' improved economic situation, but also to the growing acceptance of technical fibers, as the share of technical fibers in the total volume rose between 1985 and 2010 from 46 to 68 % – at the expense of cotton. Alongside viscose fibers, polyester fibers are seen as having the greatest growth opportunities. Parallel to an increase in the fiber production which is predicted to continue in the coming years, environmental consciousness and the dwindling raw material resources are becoming more and more noticeable in this branch. Added to this are the rising raw material prices which are making an alternative raw material supply ever more lucrative. For polyester fibers which, thanks to their outstanding mechanical properties, the ease of processing and the low material costs, are enjoying a steadily growing demand, there is an interesting opportunity for reducing raw material costs. The use of post-consumer reclaim (PCR) which generally comes from collection systems for PET bottles makes the fiber production both more economical and more ecological.

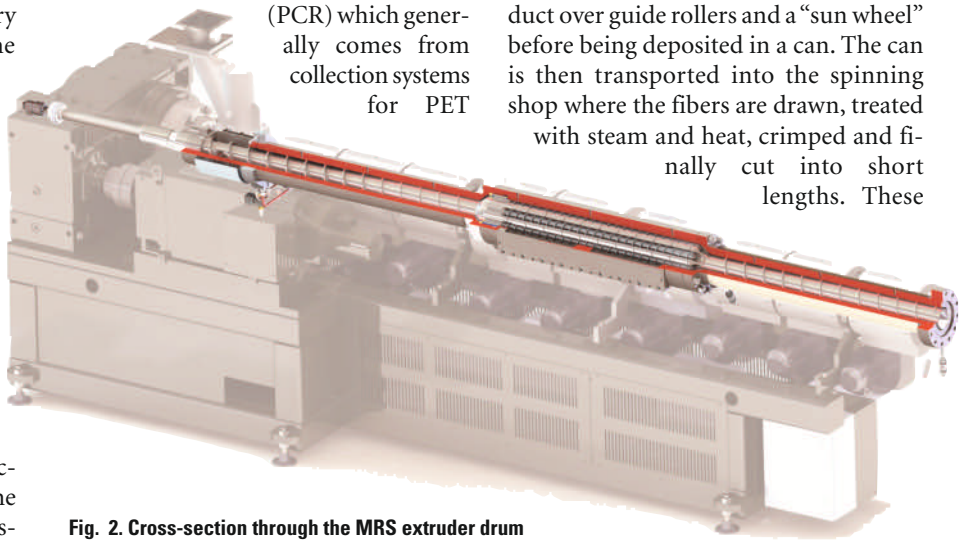

Fig. 2. Cross-section through the MRS extruder drum

Fiber Production and Applications

A fundamental distinction is made for the staple fiber production between single-stage and two-stage processes. While the single-stage process functions without buffer store, the fibers are collected in cans after production and before drawing and buffer stored in the two-stage process: After melting of the PET pellets in an extruder, the melt is discharged through fine dies and via a cooling air duct over guide rollers and a "sun wheel" before being deposited in a can. The can is then transported into the spinning shop where the fibers are drawn, treated with steam and heat, crimped and finally cut into short lengths. These short lengths, small staples, give the staple fiber its name. In a further work step, the fibers can be spun together with others to form a yarn and then be further processed. Different die forms and versions also allow the production of hollow fibers or multi-component fibers for a wide variety of applications, such as →

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fillings for sleeping bags, winter jackets, pillows and hygiene articles **(Fig. 1)**.

Components of the Extrusion Line

In the process described, various system components play an important role. This article examines in more detail the extrusion line up to the spinneret. It consists of the extruder that is responsible for the gentle melting and homogenization of the melt, and a melt filter to ensure that a clean melt is delivered to the melt pump; this is very important, particularly when using reclaim. The melt pump, in turn, is responsible for ensuring the sufficient pressure is built up for the downline spinneret. And finally a viscometer and a corresponding rule ensures that the melt always has exactly the viscosity required for the spinning process.

For some years now, Gneuss Kunststofftechnik GmbH, Bad Oeynhausen, Germany, has been offering a tailor-made machine combination consisting of a Multi Rotation System (MRS) extruder, RSFgenius rotary melt filter and VIS online viscometer that has made a name for itself in the PET recycling sector. This unique machine combination offers specific benefits also for staple fiber production.

MRS Extruder with Degassing and Viscosity Control

The key role in the processing of PET reclaim is played by the MRS extruder that ensures not only the melting and homogenizing of the plastic, but also the optimum setting of the melt viscosity with its special evacuation zone. This is made possible by its unique design with an enormously large melt surface area.

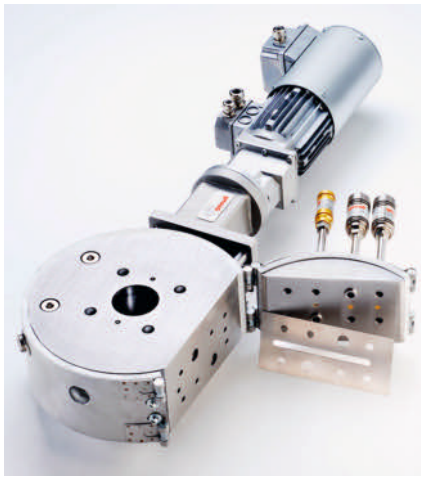

Fig. 4. VIS online viscometer

Fig. 3. RSFgenius rotary filter system, patented, with screen elements mounted in a ring on a filter disk

The main problem during the processing of PET reclaim is the moisture which at the high processing temperatures in the extruder causes in a hydrolytic degradation of the polymer chain, and hence a decrease in viscosity. It has therefore been common to date to dry the ingoing material before processing. The raw material is dried in large drying machines over a period of up to 8 hours and at temperatures of up to 200 °C. The associated enormous space requirement, investment costs, energy consumption and maintenance can now be minimized with the unique extruder as it performs several functions at the same time.

The MRS extruder is designed as a single-screw extruder with a special degassing zone in which the polymer stream is guided onto a rotating single-screw drum. The drum contains eight small extruder barrels with "satellite" screws parallel to the main screw axis. These "satellite" screws are driven by a ring gear. They rotate in the opposite direction to the main screw as they rotate around the screw axis. The extruder barrels cut into the drum of the MRS are approximately 30 % open on the outside to ensure an optimum melt transfer into the barrels, so that the evacuation can take place unhindered. Furthermore, precise control of the melt temperature is possible as the temperatures of all the surfaces in contact with the melt can be controlled accurately **(Fig. 2)**.

The large and constantly renewed polymer surface area that is around 25 times larger than that of a co-rotating twin-screw extruder permits an unrivalled degassing performance even with a very moderate vacuum. By contrast with conventional extrusion systems, a vacuum of between 25 and 40 mbar is sufficient here to achieve the desired effect even with a high initial moisture content. With this process engineering design it is possible to shift the chemical equilibrium reaction of the hydrolysis by removing the moisture in order to achieve longer-chain polymers and to set the optimum viscosity required for the fiber process without predrying of the raw material. Moisture and other volatile constituents can be removed continuously.

Automatic Melt Filter

Minor impurities in the melt stream are just as much an obstacle during the processing of reclaim as moisture. These impurities such as sand or residues of paper or labels can lead to problems, especially during the production of the extremely thin staple fibers. Furthermore, the melt has to be delivered pulse-free and uniformly from the spinneret. For this reason, "spinpack filters" are employed in staple fiber lines to homogenize the flow profile and ensure the purity of the melt. These generally consist of several layers of wire mesh. Impurities in the melt

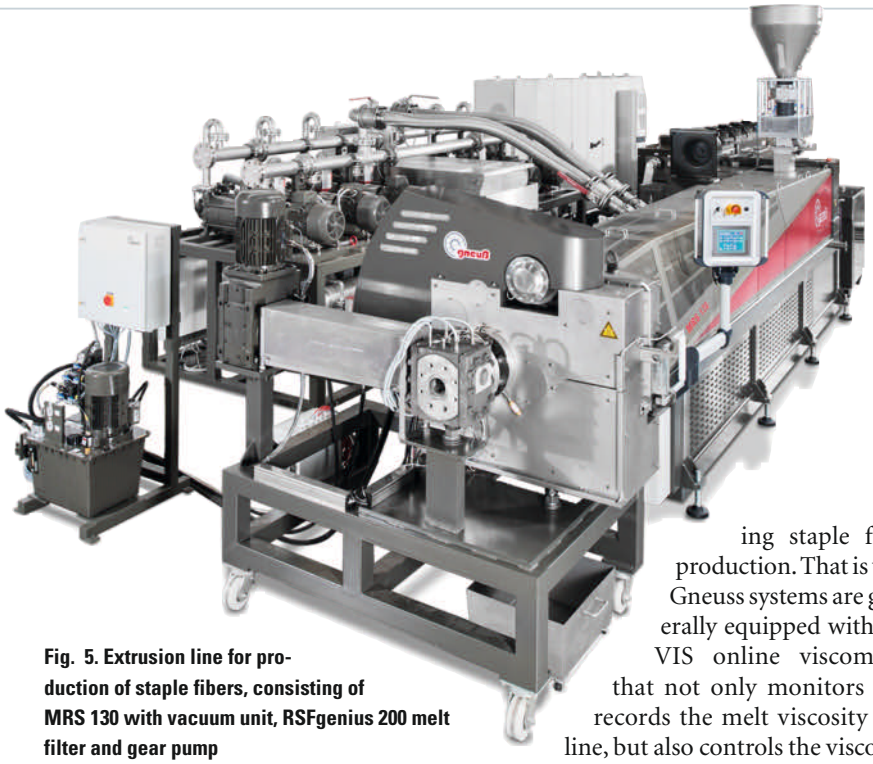

Fig. 5. Extrusion line for production of staple fibers, consisting of MRS 130 with vacuum unit, RSFgenius 200 melt filter and gear pump

stream gradually cause the spinpack to clog so that it then has to be changed; this is generally only possible during a standstill of the line. The finer the spinpack mesh is chosen (generally 20-75 µm), the more frequently it has to be changed. It therefore makes sense to install a melt filter between extruder and spinpack **(Fig. 3)**.

The RSFgenius rotating filter system operates with screen elements mounted in a ring on a filter disk that passes through the melt channel. As the plastic melt flows through the filter, the dirt particles collect on the surface so that the differential pressure increases slightly. The control system reacts to this increase in pressure and allows the filter disk to advance by approx. 1°. As a result, the contaminated filter area is continuously moved out of the melt channel and fresh filter area into the channel without the active filtration area changing. Thanks to this operating method, the filter system operates continuously and with a constant pressure, both of which are crucial for the staple fiber production. Screen cleaning is also fully automatic without interrupting the production process. Depending on the filter mesh size, the screens can be used up to 400 times, corresponding to fully automatic filtration of several days or even weeks without the need for personnel.

Online Viscometer for Recording and Control

Optimum setting of the viscosity is one of the most important preconditions during staple fiber production. That is why Gneuss systems are generally equipped with the VIS online viscometer that not only monitors and records the melt viscosity online, but also controls the viscosity by intervening in the process **(Fig. 4)**.

For this a small part of the polymer melt is separated from the main melt channel by a high-precision metering gear pump. This is then pumped through a precisely manufactured slot capillary. Both the melt temperature and the melt pressure are measured at two points. On the basis of internal calculations, VIS determines a value for the representative shear rate and the corresponding representative viscosity. It is thus possible to keep the melt quality within a very close tolerance band during the processing of polyester, even with fluctuating moisture contents of the ingoing material. After determining the viscosity using pressure and temperature sensors, the vacuum at the evacuation zone of the MRS is controlled so that the viscosity and hence the mechanical properties of the melt are maintained at their nominal values. Apart from setting the desired product characteristics, the online viscometer thus ensures that less scrap is produced and a high cost-effectiveness of the process is ensured.

Throughput Increased and Energy Saved

Several producers of staple fibers already use an MRS extrusion line, including a leading Brazilian PET processor, a company in Belarus and the only producer of staple fibers from rPET in the Czech Republic, Silon s.r.o. in Prumyslova. Silon is regarded as the leading producer of staple fibers in Europe and operates an MRS 130 with vacuum unit, RSFgenius 200 melt filter and gear pump **(Fig. 5)**.

The MRS extruder replaced an old single-screw extruder in the fiber line and increased the maximum output by around one-third. Thanks to the advantages of the multi-screw extruder already described, the drying and crystallization unit previously used is no longer required, and nevertheless material with a moisture content of up to 2 % can still be processed. It has thus been possible to drastically reduce the energy consumption of the whole plant without detracting from the product quality. With this reduced energy consumption and the possibility of using resource-conserving recyclate, the line is a perfect response to the ecological and economic demands of the growing staple fiber market. ■

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