Compounding of Polycarbonate: Advantages of the Co-Rotating Fully Intermeshing Twin-Screw Compounding Extruders Technology

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Introduction

The co-rotating, fully intermeshing twin-screw extruder is the primary production unit for compounding of polymer based materials. Coperion has delivered its first co-rotating, fully intermeshing twin-screw compounders type ZSK for compounding of Polycarbonate more than 30 years ago and has meanwhile the largest population of extruders for manufacturing polycarbonate as well as for compounding polycarbonate, e.g. alloys with ABS or filled with glass fibers, talc or pigments.

High torque (power) designs (ZSK Mc^{18} & STS Mc^{11}) and the use of increased rpm (1200 rpm and 900 rpm) in conjunction with high throughput rates have improved operating flexibility and productivity.

The key feature of the co-rotating, fully intermeshing twin-screw extruder design is the self-wiping characteristic of one screw with respect to the other. This eliminates stagnation and eventual degradation of material as it is transported along the length of the compounding extruder which is important as transparency is one key property of Polycarbonate. Polycarbonate as a clear, colorless polymer is used extensively for engineering and optical applications.

Coperion and its high precision manufacturing facilities in Stuttgart (Germany), Wytheville and Ramsey (USA) and Nanjing (China) ensure the best quality and performance for its co-rotating, fully intermeshing twin-screw extruders (ZSK, STS and CTE)

However, one of the most significant steps forward in compounding of Polycarbonate was achieved with the identification of the fundamentals of high rpm / high torque compounding technology.

High torque, high rpm co-rotating twin-screw compounding technology

Since the introduction of the first high torque, high available rpm ZSK MEGAcompounder (Mc) in the mid 1990's, new advances in power transmission technology (gearbox as well as screw shaft design and material of construction) have permitted an additional 50% increase in torque capacity from the Mc power volume factor (PVF: Md/a^3 [Md = torque, a = centerline distance]) of 11.3 to the Mc^{18} PVF of 18.

The impact of this advancement in power transmission capacity is a result of significant increase in productivity (production rates), efficiency and system flexibility for compounders.

The key to the success of this technology is the increase in the power (torque) transmission capacity in combination with increased screw rpm.

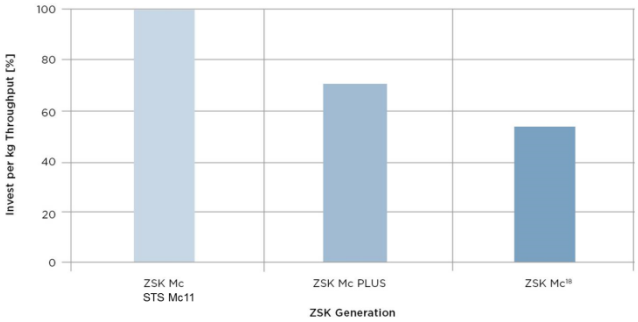

Fig.1: Performance diagram for high torque / high rpm twin screw extruders

As shown in Fig. 1, the ZSK Mc^{18} has the best rating in terms of invest per kg throughput due to the highest torque level.

Manufacturing of Polycarbonate

The ZSK technology is used directly linked to the polymerization of the polymer. Different technologies have been developed in the past. The main polycarbonate material is produced by the reaction of bisphenol A (BPA) and phosgene $COCl_2$. The Interface polymerization was the most common in the past, whereas the polymer finally was diluted in a solvent. The ZSK technology is widely used for the separation of the solvent (e.g. Dichloromethane, hexane) from the polymer with a polymer concentration between 50 and 99 %.

An alternative route to polycarbonates entails trans-esterification from BPA and diphenyl carbonate (DPC) without solvent. Also for this technology the ZSK is widely used for different process tasks, e.g. stabilization or degassing of residuals.

In general, downstream of the ZSK a screen pack changer is used for general purpose (GP) as well as for optical purpose (OP) grades. The filter size depends on the final quality and ranges from 10 micron to 150 micron.

Special materials of construction are widely used (focus iron-free) in order to achieve a high level of transparency, see Fig. 2.

Fig.2: TiN layered screw elements for manufacturing of Polycarbonate.

Production results are available for machine sizes up to a ZSK 250 Mc for manufacturing GP and OP grade quality resins.

Compounding of Polycarbonate

One important process is to transfer polycarbonate powder or flakes into pellets, whereas during this compounding step the polymer is stabilized, degassed and also filtered.

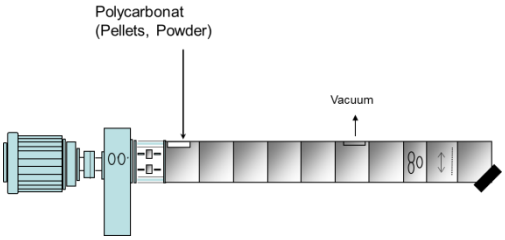

Fig.3: Machine set-up for Polycarbonate Compounding.

The machine set-up to transfer polycarbonate powder or flakes into pellets can be seen in Fig. 3. The polymer is fed into barrel 1, plasticized, stabilized and homogenized within a L/D < 28. The degassing domes often need to be heated to prevent condensation inside the walls of the vent port because polymer melt or crumbs may stick on for a longer period of time, become thermally degraded and back in to the screw flights and will contaminate the polymer. Side–vents can be used to ensure that condensate or degraded polymer cannot re-enter the product flow of the ZSK (see Fig 4). The typical throughput range for general purpose for a ZSK 133 McPLUS is up 6000 kg/h.

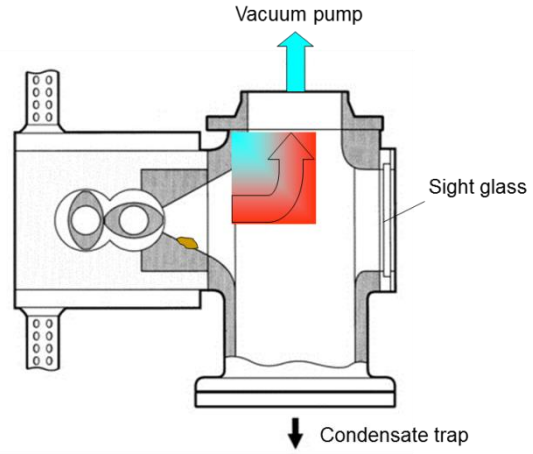

Fig. 4: Side vent at ZSK

The benefits associated with the increased torque on the ZSK 58 Mc^{18} compared with the ZSK 58 McPLUS and ZSK 58 Mc (Figure 5) are clearly illustrated in the example presented for ABS / PC alloying with short glass fibers up to 20%wt, and a high speed of up 1200 min^{-1}. As in the case of ABS/PC, the system permits a higher degree of filling. As a result, output increases up to 2000 kg/h on a ZSK 58 Mc^{18}, in other words more than 30% compared to the ZSK McPLUS.

Fig.5: Throughput for ABS/PC blends

PC/ABS compounds have a better low temperature impact resistance advantage over PC as well as excellent dimensional stability and strength.

Direct extrusion of Polycarbonate

Another common application for the ZSK technology and Polycarbonate is the direct extrusion of the polymer into sheets. Polycarbonate pellets and additives are fed into barrel one, melting and homogenized as well as volatiles removed via the vacuum zone. The pressure built-up for the screen pack changer and the die is generated by melt pump. The biggest benefit using the ZSK for direct extrusion is the outstanding mixing performance in case of alloys compared to other machine systems.

Summary

Significantly higher throughput rates are achieved when polymers can be processed at high rpm and torque. Especially polycarbonates and their compounds can benefit significantly from the development by Coperion towards high torque and high rpm. The throughput rate therefore has been increased from 1995 (MEGAcompounder) to 2015 (Mc^{18}) for the machine size by more than 300%.

The ZSK technology is also used directly after the polymerization, e.g. for devolatilitzation of the solvent or stabilizing and filtering for different polycarbonate grades. Using the ZSK for devolatilization has been successful realized in the industry due to much energy balance, continuoes processing combined with its fully self-cleaning design.