SULZER

TECHNICAL ARTICLE

How thermal stability and efficient mixing leads to significantly higher quality polymers

In today's competitive polymer market, achieving high product quality while maintaining operational efficiency is paramount. This technical article explores how advanced thermal management and static mixing technologies can significantly enhance polymer production across three critical stages: reaction, devolatilization and upgrading.

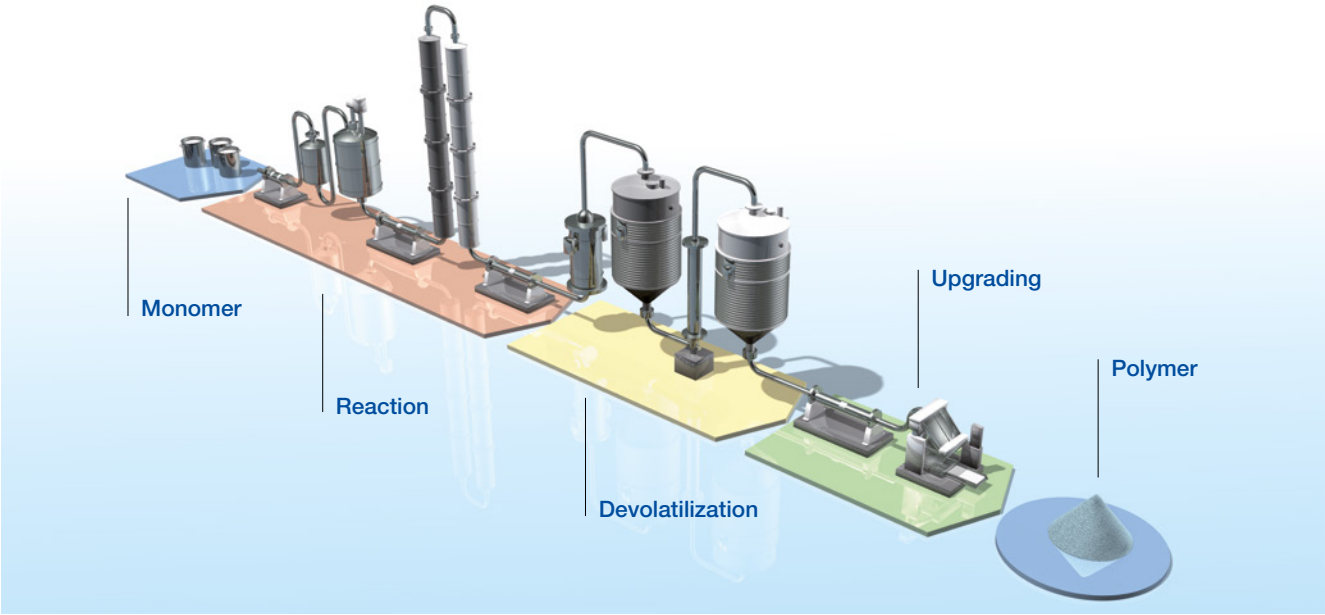


Figure 1: While the solutions presented here can be used in an end-to-end process as highlighted in this figure, they can also be applied on a stand-alone basis within an existing production scheme.

Polymerization is typically an exothermic process. Without precise heat control, hot zones in reactors can lead to unwanted side reaction, degradation and loss of product quality. **Maintaining stable thermal profiles in the reaction step is critical to ensure uniform polymer chain lengths and high conversion rates.**

After polymerization, polymers often still contain solvents and unreacted monomers which need to be removed. The growing demand for polymers targeting specific applications and use cases, like polyolefin elastomers (POEs) used in electric vehicles and solar panel encapsulants, can place additional constraints on the process, such as **low shear and precise temperature limitations**. These constraints can render the extruder style of devolatilization ineffective, making **static devolatilization systems the solution of choice.**

The **blending of polymers with additives** with special properties, such as for UV stabilization or fire resistance, play a crucial role in customizing materials for their end-use. The **development of high-performance compounds and masterbatches requires predictable and efficient mixing** of polymers, fillers and additives. Traditional mechanical solutions, while effective, have the tendency to overwork and introduce unwanted shearing to specialty polymer blends. This is where the low shear static technologies are applied.

Reaction

Effective thermal management is one of the most critical—and often underestimated—challenges in polymer manufacturing. As polymerization reactions are inherently exothermic, if this heat is not efficiently and uniformly removed, it can lead to a cascade of processing issues.

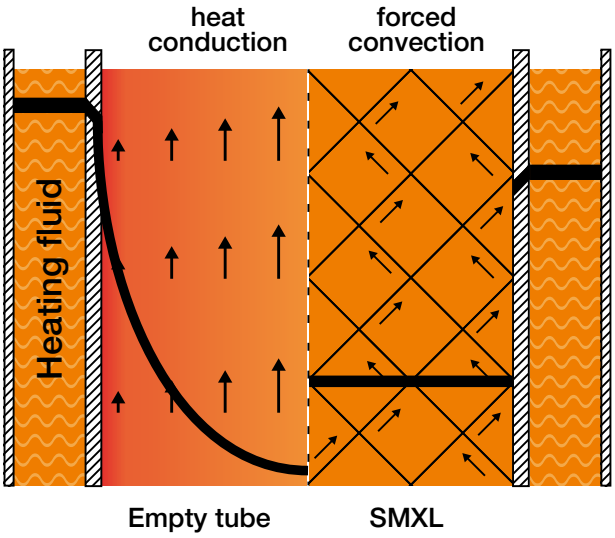
Whether operating batch or continuous systems, producers must implement robust thermal control strategies to ensure quality, efficiency and competitiveness in today's demanding polymer markets.

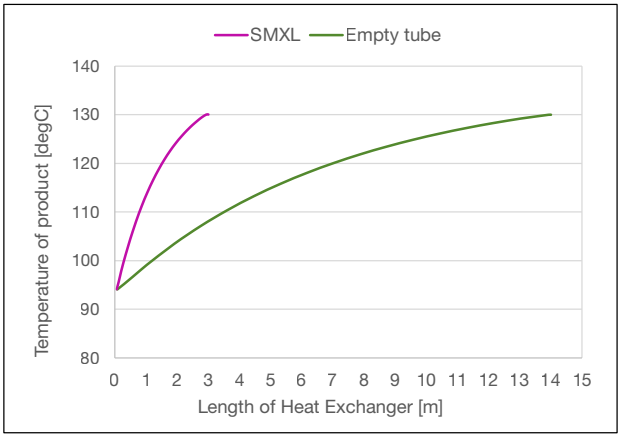
Traditional polymer reactors, such as stirred tanks, often struggle with efficient heat removal. Their limitations in managing the exothermic heat, especially with increasing viscosity, can lead to stagnant flow zones, uneven cooling, inconsistent temperature profiles and potential quality issues.

Furthermore, the conventional stirred tank systems introduce operational complexities. Requiring agitators and other rotating parts, they lead to increased maintenance requirements and higher operational expenditures (OPEX). In contrast, our static solution eliminates moving components, offering a superior alternative. Two such examples are detailed below.

SMXL™ Heat Transfer

The empty tube shown in the diagram below represents a conventional heat exchanger. The laminar flow of the material through the tube causes a wall effect where the material closest to the wall sees the highest temperature. This leads to a temperature gradient across the polymer material that is being heated, resulting in the quality and consistency issues outlined above. Thanks to the radial mixing resulting from the heat exchanger inserts, the heat transfer is significantly increased compared to a heat exchanger without inserts, allowing the system to operate at lower wall temperatures.





An SMXL heat exchanger conversely offers superior performance through action within the tube that effectively renews the surface of the material touching the surface, allowing increased heat transfer and eliminating the high temperature gradient within the material being heated.

The reduction in length is significant, as indicated above, where deltas in temperature can be achieved in around 3 meters of tube length compared to 14 meters for the conventional solution. This represents a reduction in the tube length of close to 80%. This translates to significant savings in the footprint, energy use and capital expenditure for plastic producers.

SMR™

Sulzer SMR mixer reactor is built with mixing elements made from bent tubes. These allow heat transfer fluids to flow through the structure, thus creating a mixing element with temperature-controlled surfaces. Water, thermal oil or other special cooling media can be used as heat transfer fluid. The special tube bending pattern provides a very high specific heat transfer area, intensive radial mixing and a narrow residence time distribution. The SMR mixer reactor is the ideal equipment for the execution of even very highly exothermic reactions, such as polymerizations. As a heat exchanger, it is applied mostly in cooling where fluid viscosity is increased as temperature is reduced.

Even at high flow rates, there is no separation of the product stream into parallel substreams, i.e., there is no maldistribution. Low shear ensures gentle treatment of the product.

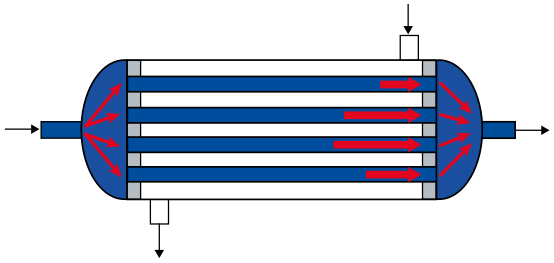
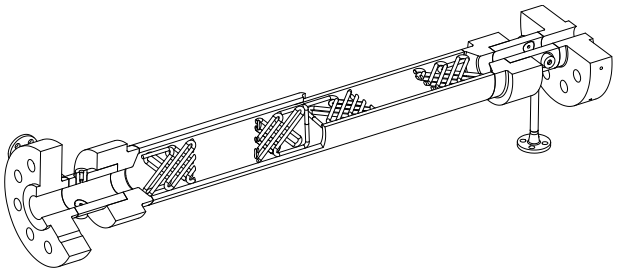


Figure 2. Multitube heat exchangers risk maldistribution when cooling viscous polymers due to temperature-sensitive viscosity, leading to uneven flow, reduced performance and potential clogging.



Cutaway of the Sulzer SMR™ reactor

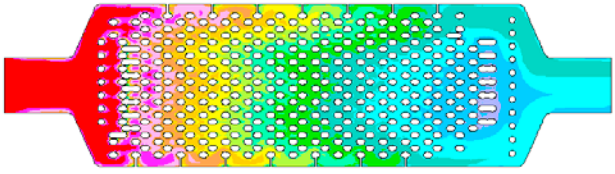


Figure 3. SMR heat exchanger avoids maldistribution through its monotube design, where the product flow is undivided in a single flow channel, ensuring homogeneous flow, viscosity, and temperature, and preventing clogging.

Summary

Both mixer solutions are static, with no moving parts, and inherently designed to transfer heat evenly to the polymer. Developed through decades of process engineering and field application, the SMR integrates advanced heat management and mixing into a single, static device. Key to the success of these solutions is the high surface area, which transfers heat efficiently and allows for a smaller overall footprint, in addition to the low shear action that is vital for many viscous melts. The lack of moving parts also ensures maintenance is simplified. Compared to a traditional heat exchanger, reductions of up to 80% in the length translate to smaller footprint sizes, lower capital cost, more efficient heat transfer and better thermal control for polymer producers.

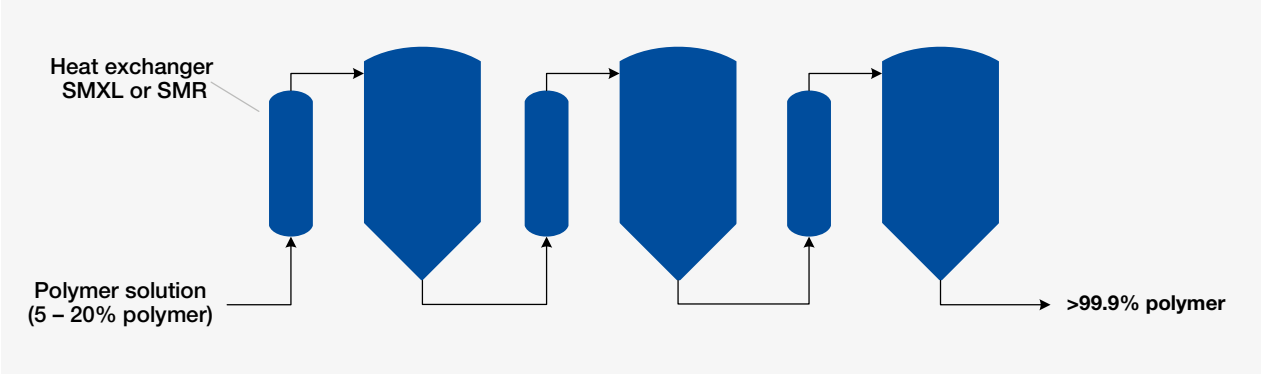
Devolatilization

After the reaction stage, the virgin polymer can still contain solvents and unreacted monomers. These impurities, left behind after polymerization, can critically impact product specifications, performance and compliance with increasingly stringent regulatory standards.

Consistent removal of the remaining monomers is key to reliable polymer production. There are many solutions available for this in use today. The process can contain multiple stages where the volatiles (additives and monomers) are removed. The most critical step in the process is the final stage, as this is where the final product specification is achieved. One solution for the final stage is a degassing extruder, where the material is heated in the single or twin extruder to release the unreacted monomers and solvents from the polymer. However, this method typically applies high stress to the material and can lead to unwanted properties in the melt being produced, as well as high maintenance costs due to rotating equipment.

For the removal of residual solvent and monomer in shear sensitive materials, Sulzer offers a sophisticated **devolatilization technology that combines efficiency, product integrity and operational simplicity**. At the heart of this solution is Sulzer's multi-stage static flash devolatilization system, engineered to achieve high levels of volatile removal. This ensures that even sensitive polymers are processed without degradation.

Devolatilization technology



Sulzer's devolatilization technology, DEVO™ streamlines solvent and unreacted monomer removal in a multi-stage process that increases the polymer concentration from initial concentrations of 5-20 wt.% to the required residual solvent level, typically achieving > 99.9 wt.% polymer concentration. This multi-step design can be specifically engineered to ensure that the product quality is maintained. This is achieved by varying the number of degassing stages according to the needs of the process, which is verified in our pilot facilities.

DEVO is ideally suited for a wide range of polymer applications. These include biopolymers, such as PLA and PCL, where thermal sensitivity is a key concern; commodity polymers like polystyrene and polyolefins; and solvent-based recycling processes, where effective removal of contaminants is essential to ensure product compliance and performance. Sulzer devolatilization technology is also ideal for applications such as solvent removal.

Here is a list of the applications where the DEVO technology is applied:

> Polystyrene, GPPS, HIPS
> Styrene copolymer, ABS / SAN
> Polyethylene, HDPE, LLDPE
> Polyvinylacetate, PVAC
> Polyethylacrylate
> Polyisobutylene
> Polycarbonate, PC
> Polyetherglycole, PEG
> Polyoxymethylene, POM
> Polyisobutylene, PIB
> Elastomer, EPM, EPDM
> Biodegradable polymers PLA, PCL

DEVO has been proven in more than 40 references with scales of up to 450 kt/a, achieving the remaining VOC level in the parts per million (ppm) range. The technology's reliability is enabled and reinforced by extensive testing facilities in Switzerland, ensuring that scale-up from small technical size to industrial capacities is seamless and predictable.

	Advantages of Sulzer DEVO technology over degassing extruders
Investment costs	Reduced investment costs since: > DEVO technology significantly benefits from economy of scale. > Mainly static equipment is used instead of rotating equipment. > Reduced OSBL costs through reduced electric transformer size by > 90%.
Operating expenses	Reduced operating expenses due to: > Using traditional heat sources or waste heat instead of electricity, where feasible. > Reduced maintenance costs since gear pumps are the only rotating equipment.
Process advantages	> Excellent temperature and pressure control in all three stages. > About 90% reduced shear stress, significantly reducing the loss of molecular weight. > Increased residence times of the polymer, eliminating diffusion induced limitations in degassing extruders. > Single technology system for the whole degassing process. > Easy to scale-up. > Proven technology on industrial scale.
Design flexibility	Design can be fully tailored to the application, unlike degassing extruders, which are typically supplied in standard sizes.

Summary

Unlike conventional systems that risk temperature overshoots or excessive shear, Sulzer's devolatilization design ensures precise thermal control. This **eliminates the risk of polymer degradation** and maintains the integrity of molecular structures, resulting in a stable final product. Operating under low shear conditions, the system consumes significantly less energy, which contributes to lower overall operating costs. Its compact, modular design simplifies integration into existing production lines and reduces maintenance requirements.

Ultimately, this degassing step is not just a technical requirement—it's a value enabler. It turns a chemically reacted intermediate into a commercially viable, application-ready product.

Upgrading

Now that the polymer has been reacted and the volatiles have been removed, the next step is the addition of additives and fillers to ensure that the final polymer blend is finished and fit for the purpose it was produced for.

Static mixers offer an efficient, reliable and cost-effective solution for polymer manufacturing, particularly where precision and gentle handling are critical. Unlike dynamic mixing equipment, they feature no moving parts, which minimizes maintenance and enhances long-term operational reliability—resulting in a significantly lower total cost of ownership. These mixers play a vital role throughout the production process: homogenizing additives like catalysts, initiators and functional chemicals before or during polymerization; blending masterbatches and modifiers prior to palletization to ensure consistent color, performance and composition; and finally, achieving melt homogenization in the finishing stage by equalizing viscosity, temperature and color to deliver a uniform, high-quality polymer melt ready for shaping or further processing.

Technologies such as the SMX™ and SMX™ plus geometries are at the heart of Sulzer's high efficiency mixing. By integrating them before pelletization, producers can reduce downstream formulation steps, improve cost efficiency and deliver consistent, specification-ready polymer products.

Blending or compounding of two polymers

When two different polymers have to be mixed together to form a compound, dynamic systems such as extruders are often used.

Static mixers, however, show equally good results in compounding different polymers, while having the advantage of **low maintenance costs and spare requirements.** For most compounding tasks, the required shear forces are not very high. Therefore, Sulzer static mixers provide a true and cost-effective alternative for compounding polymers.

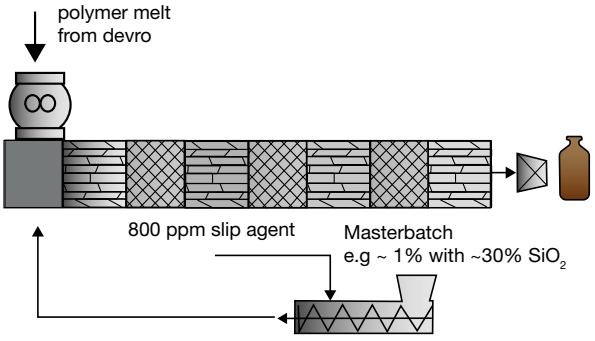
CFD simulation of a Sulzer static mixer for compounding two polymers of similar viscosity

Another key benefit of static mixers is their ability to deliver thorough mixing with minimal pressure drop across the system. This is particularly valuable in high-viscosity polymer melts, where pressure control is critical. The design also ensures extremely low shear stress, protecting sensitive polymers from mechanical degradation. With short residence times and highly controlled flow characteristics, these mixers ensure consistent and repeatable results without compromising product quality.

Admixing of low-viscosity additives in polymer melts

A common way to incorporate additives into polymer melt is to use masterbatches, that is, concentrates of additives in a polymer carrier.

In particular, solid additives (for example, pigments and fillers) cannot be admixed directly into a melt stream. In such cases, the masterbatch can be fed into the main polymer stream through a small side extruder.



Plant configuration for admixing masterbatch into a main polymer stream

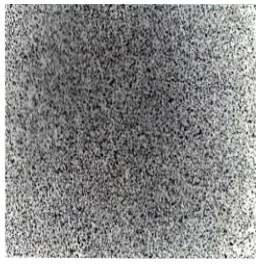
Many additives used in the polymer production industry are of low viscosity and are only partly soluble in the polymer melt. Normally, the homogeneity requirements are very high since the polymer is often pelletized immediately after the static mixer, and small inhomogeneities may result in strand breaking.

Sulzer's SMX and SMX plus static mixers, together with Sulzer's vast experience in admixing low-viscosity additives into polymer melts, enable even viscosity differences of up to six orders of magnitude (10^6) to be handled, while still achieving excellent homogeneity at the end of the mixer.

The below images demonstrate the uniformity achieved with a SMX mixer compared to an extruder. The SMX clearly shows a more uniform distribution of the TiO_2 in the polymer melt in comparison with the extruder.

Extruder

SMX



Grain distribution of 5% TiO_2 masterbatch in pellets

Summary

Whether in traditional polymers or next-generation bioplastics, **static mixers deliver consistent quality, efficient processing and lower operating costs**—making them an indispensable tool in modern polymer production.

Conclusion

From heat-sensitive polymerization to solvent removal and final melt blending, Sulzer's advanced technologies provide a holistic, integrated solution for modern polymer production. The combination of reactors, devolatilization units and static mixers delivers operational efficiency, product consistency and economic value—especially in high-demand sectors such as biopolymers, electric vehicles and renewable energy.

With a track record of proven performance, Sulzer is ready to support your polymer production needs with robust, scalable and sustainable technologies.

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