Polymer Production Technology

Sulzer Chemtech's value proposition in the production of polymers

Production of polymers using static mixing technology

Sulzer Chemtech is the world's most renowned supplier of equipment and related solutions in the field of static mixing. The combination of engineering expertise and many years of application know-how enables Sulzer Chemtech to provide global solutions for improved polymer product quality. All Sulzer Chemtech products and services rely on a successful integration of three main competencies:

- Static mixing know-how
- Piloting & scale up
- Process & equipment engineering

The road to success is with the customer

A history of successful projects clearly indicates that only a team effort involving both the customer and Sulzer Chemtech creates value for both partners. The customer provides projects with insight into the chemistry and process details, while Sulzer Chemtech provides pilot testing and broad expertise in static mixing. Newly created, innovative solutions are protected by secrecy agreements that safeguard the interests of both partners and their respective contributions.

Global support – where and when you need it

Regardless of your geographic location or the size of your project, Sulzer Chemtech's global presence means you will have the support you need. We talk your language and understand your requirements equally well for a single static mixer or for a more complex process solution. Sulzer Chemtech always provides solutions with a focus on process efficiency and the quality of polymer.

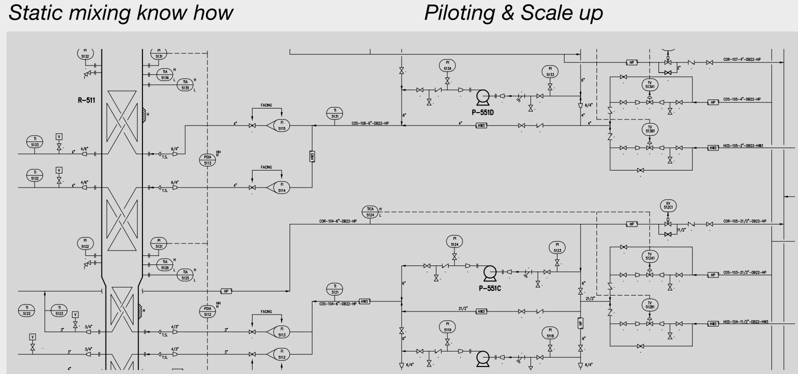
Creating value for the polymer industry

The combination of static mixing know-how, piloting and scale up, and process and equipment engineering enables Sulzer Chemtech to provide customized solutions and a process guarantee. This service is greatly linked to the availability of a piloting facility for reliable process solutions. We offer the flexibility of conducting piloting programs at our own or directly at a customer's site. Individual components for piloting as well as fixed installed equipment are at the customer's disposal. Whatever the required approach may be, Sulzer Chemtech is a reliable, global partner for optimized process solutions and related equipment.

Proven technology and proven components for the production of Your Polymer

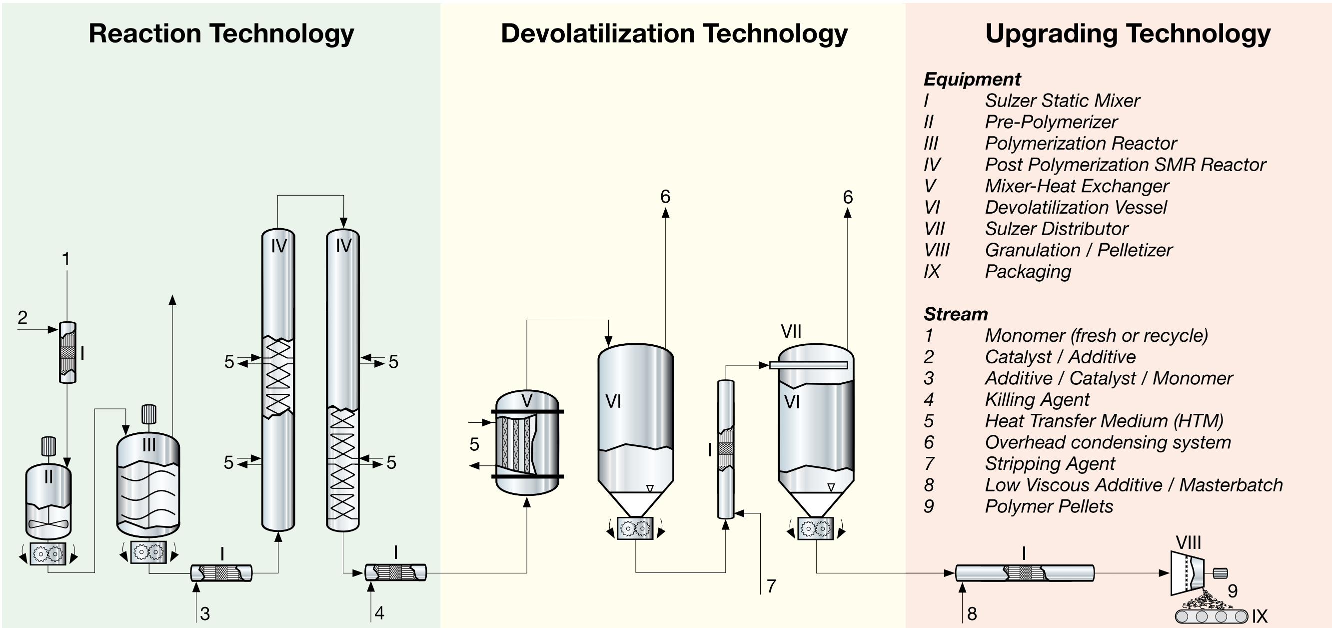
Static mixing know how

Piloting & Scale up



Process & Equipment Engineering

Sulzer Chemtech technologies



Sulzer Chemtech has developed and introduced a new generation of reactors based on the principle of static mixing and on the continuous bulk polymerization, e.g. mass- and solution polymerization. This reactor is abbreviated as SMR (Sulzer Mixing Reactor) and is characterized by accurate control of heat transfer and mixing effects so that high conversion and consistently high polymer quality are achieved time after time in order to meet varied and stringent requirements.

In polymer production, devolatilization is an important operation since the polymerized product still contains a certain amount of unreacted monomers, oligomers, solvents, and other impurities. Sulzer Chemtech has developed equipment specifically for the removal of this residual material. The single or multiple stage devolatillization process features a heat exchanger with mixer inserts, stripping agent dosing mixer, and uniquely designed degassing chambers containing special polymer distributors. This equipment, with its versatile process design, does not interfere with the polymer properties achieved during the polymerization. It does remove the residuals effectively in order to meet industry and legislative requirements.

After devolatillization, additives can be mixed into the polymer in order to upgrade the final product. Sulzer has years of experience in providing successful upgrading solutions for improved product quality and profitability. Our extensive reference list includes examples of complex applications with regard to differences in viscosity, mixing ratio and homogeneity aspects.

Reaction Technology

Sulzer Chemtech has developed a new generation of reactors based on the principle of static mixing and on the continuous bulk polymerization, e.g. mass- and solution polymerization. This reactor is abbreviated as SMR (Sulzer Mixing Reactor) and is characterized by accurate control of heat transfer and mixing effects so that high conversion and consistently high polymer quality are achieved reproducibly in order to meet varied and stringent requirements.

1. Static mixing expertise . . .

. . . for plug flow reactors

A typical polymerization post-reactor consists of a set of SMR modules built in series so that several individual temperature and mixing zones are available to meet the varying process needs. As the polymerization process proceeds, the conversion increases and the monomer concentration decreases. The SMR reactor secures a close to ideal plug flow regime, keeping the diminishing driving force at the maximum possible level. It also results in a narrow residence time distribution to promote homogeneous polymer quality. This advantage is maintained throughout the spectrum of the changing polymer viscosity, even at high conversion levels.

. . . for adiabatic reactors

Efficient radial mixing effects in the SMX plug flow reactor lead to continuous equalization of concentration, temperature, and velocity so that the end result is comparable to plug flow behavior. The Bodenstein Numbers of 50/m, equivalent to ≥ 25 ideal stirred vessels, have been measured at full scale conditions.

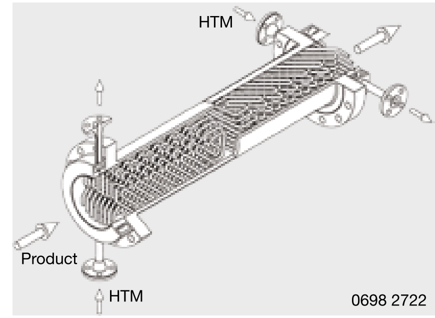
. . . for loop reactor

Individual SMR reactors can be configured into a loop reactor and are used especially for highly exothermic reactions. An excellent mixing characteristic of the SMR equipment ensures the optimal homogenization of local concentration and temperature gradients. With a densely packed heat exchange surface area, the SMR provides reliable heat removal and temperature control of polymer bulk so optimal process control is maintained. As in the common loop reactor set-ups, virgin monomer is continuously introduced to the loop while the semi finished polymer is drained and conveyed to the downstream post-reactor system.

2. Process & equipment engineering

The Sulzer Mixer Reactor (SMR) is a development based on many years of testing and experience with smaller mixers used in a variety of viscous applications. The intersecting bars encountered in static mixers are suitably replaced by tubular bundles which are adapted to the specific process and mechanical requirements of each application. This layout of tubes, similar to a static mixer, induces a product flow on the shell side that continuously transpositions the liquid layers in a regular and repeatable pattern and suppresses the development of laminar layers. This effect combines well with an extraordinarily high surface area per unit volume of equipment, and makes the SMR one of the highest performing reactor/heaters in the industry.

A performance comparison is shown in the table below.

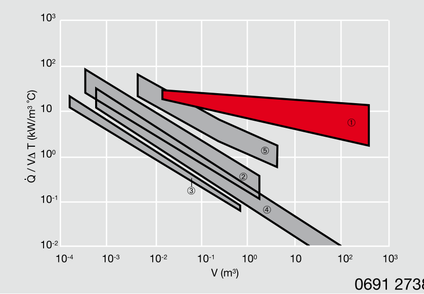


Cutaway of the Sulzer SMR reactor

1 Sulzer SMR
2 Monotube with static mixer
3 Empty pipe
4 Stirred tank
5 Extruder

The heat transfer capacity of the Sulzer SMR reactor is practically independent of the volume of the equipment.

$\dot{Q}$ = Heat flow (kW)
T = Temperature difference (°C)
V = Volume (m³)

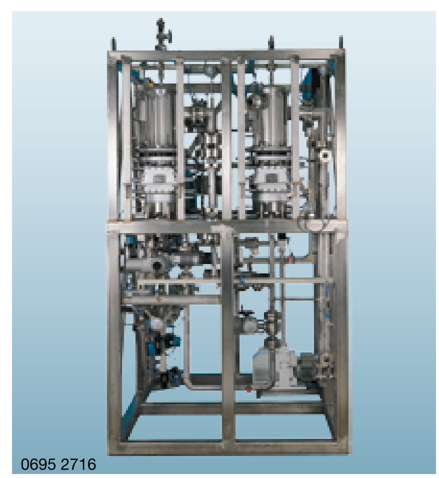


Heat transfer capacity of various type of reactors for laminar flow

3. Piloting & scale up

In most cases data like physical properties, phase behavior and operating problems are not readily available for reliable process and equipment design. Sulzer Chemtech maintains world class facilities for testing of mixing effects, heat transfer, polymerization reactions and devolatilization in order to secure reliable equipment design and desired process performance. Individual key equipment and pilot plant subsystems make it possible to tailor pilot configurations to very specific requirements.

Typical examples are:
- The effect of liquid viscosity on mixing, heat transfer and reactor performance
- The hydraulic behaviour of chemicals and products in mixing and reaction equipment
- The reaction kinetics
- Devolatilization
- High pressure dosing



Pilot skit

4. Advantages at a glance

Improved Product Quality:
- Plug flow profile results in narrow residence time temperature distribution with positive impact on the molecular weight distribution
- No channelling / no maldistribution and dead zones

High Flexibility in Production

A variety of polymer grades can be produced in one single line due to
- exact and independent process temperature adjustment of respective reactor zones
- the capability of processing fluids with a wide range of viscosities

Lower Operating Cost due to:
- reduced consumption of raw material (high conversion rate)
- prevention of large quantity of off-spec product during product grade switch
- reduced energy requirements (minimum hydraulic pressure loss, lack of agitator)
- fast self cleaning and start-up procedure

Typical applications for SMR and SMX reactors
- Polystyrene, GPPS, HIPS
- Styrenics copolymers, ABS/SAN
- Polymethylmethacrylate PMMA
- Polyethylene, PE
- Silicon polymers
- Polypropylene PP chain regulation
- Polyamide 6 PA6
- Terpene resins
- Polyoxymethylene POM and
- Biodegradable polymers

1. The concept of low residual volatile content

In the production of polymers devolatilization is an important unit operation since the polymerized product still contains a certain amount of un-reacted monomers, oligomers, solvents and other impurities. For the purpose of removal of residual materials, Sulzer Chemtech has developed equipment and a process concept based on its vast experience in static mixing. The single or multiple stage devolatilization process features a heat exchanger with mixer inserts, a stripping agent dosing mixer, and uniquely designed degassing chambers containing special polymer distributors. Combined with a versatile process design, this equipment removes the residuals effectively, but does not interfere with the polymer properties achieved during the polymerization.

2. Process and equipment design

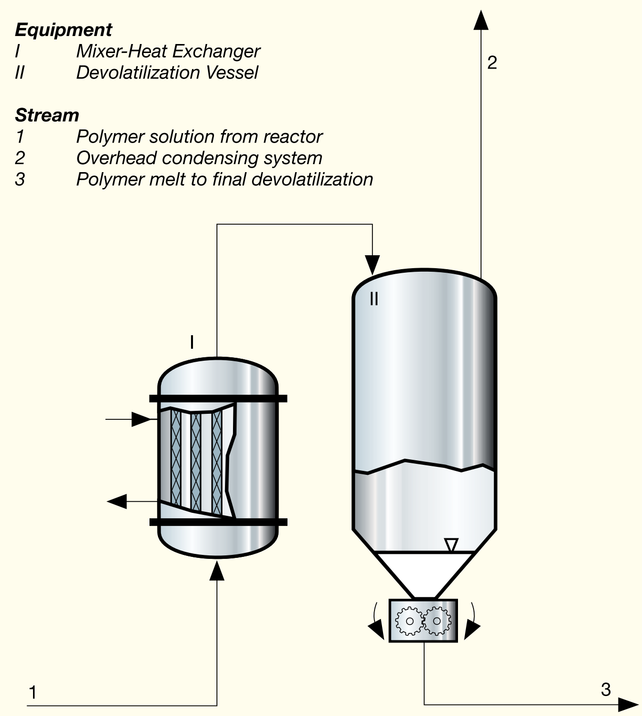
First stage

The first devolatilization stage consists of the multitube heat exchanger with mixer inserts, followed by a specially designed vacuum flash chamber. The heat exchanger secures rapid and controlled heating of the polymer solution without notable damage to the polymer properties. The separation of the residual volatiles from the polymer is carried out in the flash vessel. The de-gassed volatiles are led to a column for the separation of the oligomers. The polymer is discharged from the bottom section from the devolatilization chamber by a gear pump with special inlet section design. From there, the polymer is forwarded either to the next devolatilization stage or to the pelletizing unit.

Why a multitube heat exchanger with mixer inserts?

Unlike common multitube heat exchangers, Sulzer‘s SMXL mixer inserts induce a hydraulic regime in a prevailing laminar application that is close to turbulent. The parabolic gradients of temperature and liquid velocity across the tube diameter are successfully prevented. Sulzer‘s heater design is characterized by greatly reduced temperature differences required for the transfer of energy from heating medium to bulk fluid, by a uniform residence time distribution, and by an overall shorter residence time.

Devolatilization Technology (First stage)



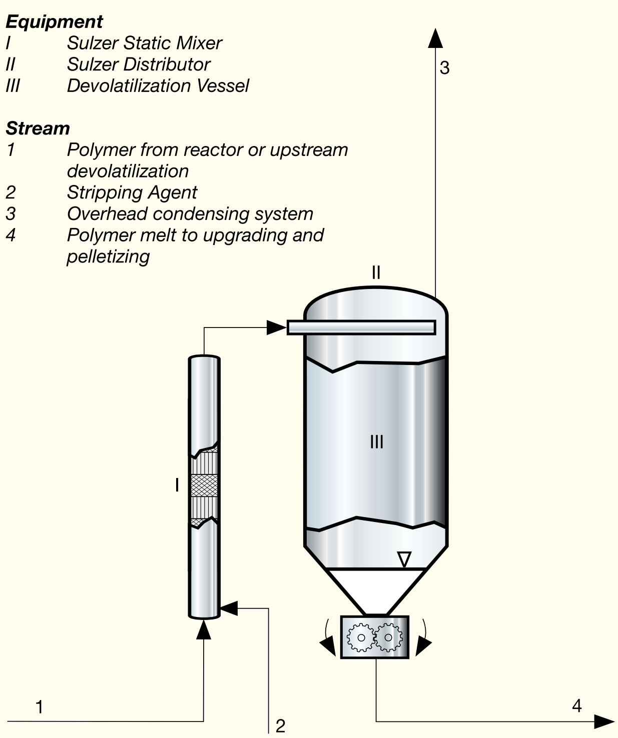
Final stage

Polymer solution, coming either from the polymerization process or from the preceding devolatilization stage, is passed to the final stage. The special treatment in this stage involves the use of stripping agent to intensify the release of remaining volatiles. The stripping agent could be water, nitrogen, CO_2, etc., depending on the application. The mixture of the polymer solution and the chosen stripping agent are flashed in the 2nd stage vacuum chamber, from where the finished polymer is discharged again by the special gear pump. The released volatiles and the stripping agent are recovered in a downstream distillation unit.

Why devolatilization with a stripping agent?

The static mixer ensures the dispersion of stripping agent into the polymer solution which turns into a foam-like phase prior to entering the sub-atmospheric devolatilization chamber. The special effect of this foam is in the reduction of the diffusion path for the volatiles so that the entire process of mass transfer is significantly intensified. For example. Devolatilization utilizing a stripping agent allows for consistent depletion of volatiles from polystyrene melt down to residue content of 100 – 200 ppm. Subject to pilot test confirmation, full process guarantees are backing our scope of supply. Sulzer Chemtech can perform devolatilization tests for new or untested polymers in order to specify the process and supply the guarantees.

Devolatilization Technology (Second stage)



3. Piloting & scale-up

Alike in section Reaction Technology data like physical properties, phase behavior and operating problems are not readily available to perform reliable process and equipment design. In Sulzer Chemtech's testing facility for mixing effects, heat transfer, polymerization reactions and devolatilization, test set-ups can be tailored to specific requirements. Devolatilization results are incorporated into the design of industrial size applications with related guaranteed performance.

4. Advantages at a glance

Investment

The capital cost is comparatively moderate due to the unique process concept and equipment without moving parts.

Operating Cost:

- reduced electrical power consumption as the result of the absence of heavy rotating equipment, e.g. extruder etc.
- reduced mechanical maintenance

Product Quality

Reduced polymer degradation due to:

- the prevention of damage to the polymer morphology by avoiding exposure to high shear forces
- the prevention of elevated process temperature by using efficient heat transfer equipment
- very low residue content

Typical applications of polymer devolatilization

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

Upgrading Technology

1. The static mixer as key to success

After the removal of un-reacted and inert materials through devolatillization, the subsequent upgrading commonly involves the admixing of additives or dye to the polymer. Sulzer has many years of experience in providing complete solutions for improved product quality and profitability for this finishing process. We maintain an extensive reference list with examples of complex applications with regard to viscosity, mixing ratio and homogeneity aspects.

2. Process and equipment design

Admixing of additives into polymer products is performed in various hydraulic regimes ranging from laminar to transitional and turbulent. The polymer additive mixing ratio defines the degree of mixing complexity, which ranges from fair to very demanding. Sulzer Chemtech's static mixing technology is based on equipment with open intersecting channels which are formed by uniquely arranged corrugated plates and bars. The mixing action itself is achieved by the continuous splitting, extension and transposition of the component streams. Successive mixing elements are rotated by 90° to ensure that local homogeneity is equalized over the entire pipe cross section.

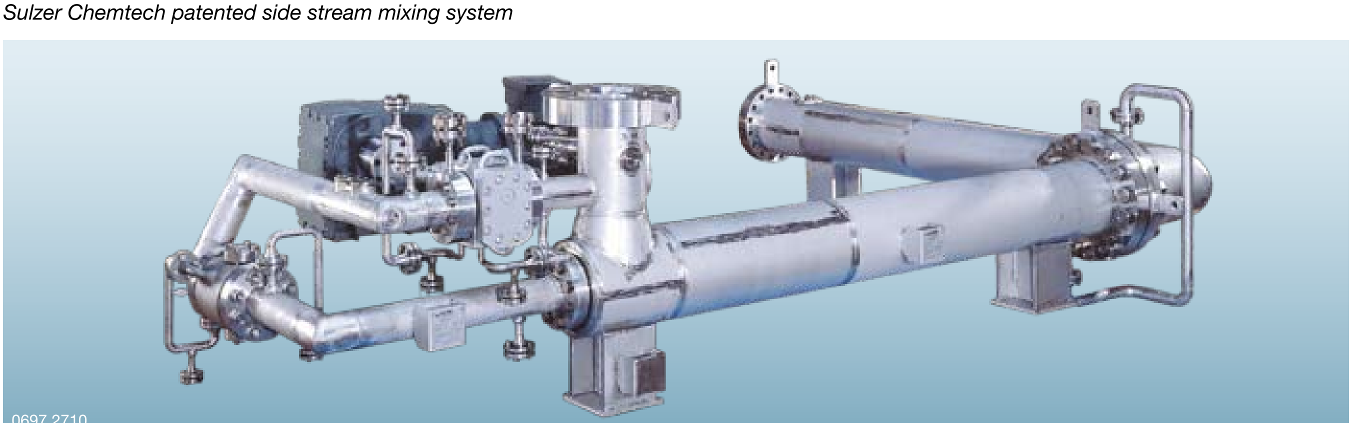
3. Piloting and scale-up

In some applications, solubility of additives in the polymer may not be known to the extent needed for reliable design. Since this property is of utmost importance for homogeneity and uniform product quality, Sulzer Chemtech has the capability of performing testing tailored to the specific project requirement and customer objectives.

Following are some of the most common applications for admixing of low viscous and semi-soluble additives in polymers where testing has provided reliable design data:

- UV- stabilizers
- antistatic agents
- antioxidants
- mould release agents
- mineral oil etc.

Sulzer Chemtech patented side stream mixing system



4. Advantages at a glance

Investment

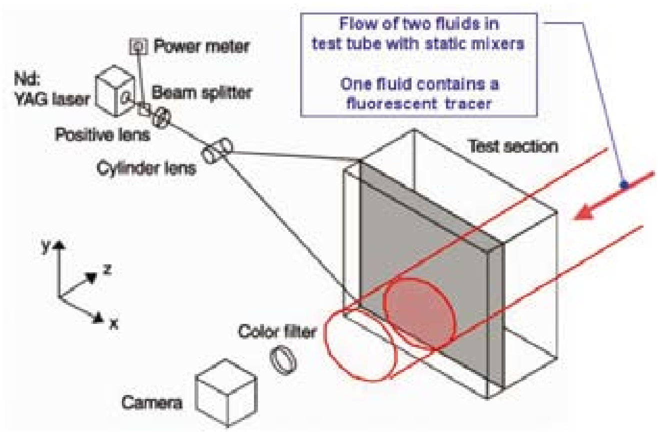
Compared to dynamic mixing equipment like extruders, Sulzer static mixing solutions are significantly lower in cost.

Operating Cost:

- Cost related to maintenance of mixer is non-existent

Product Quality

- Prevention of polymer degradation due to low shear force
- High and continuous homogeneity of additive enriched polymer



LIF principle and set-up

Section of pilot plant for polymer production

Typical applications for Sulzer static mixer

- Admixing of additives
- UV-stabilizers
- Antistatic agents
- Antioxidants
- Mould release agents
- Mineral oil etc.
- Monomers like AN, SM, AM
- Solvents like EB, chlorobenzene, methylene-chlorid
- Colorant
- Masterbatch

Polymer industries using Sulzer static mixer

- Polystyrene, GPPS, HIPS
- Styrenic copolymers, ABS/SAN
- Polymethylmethacrylate PMMA
- Polyethylene, PE (LLDPE, LDPE, HDPE)
- Silicon polymers and elastomers
- Cellulose fibre
- Polyethylene terephthalate PET
- Polyamide PA, PA6
- Viscose
- Polycarbonate PC
- Polypropylene PP
- Terpene resins
- Polyoxymethylene POM
- Biodegradable Polymers
- PBTP, PB, PBS, PIB etc.
- PUR
- Teflon
- Adhesives
- Special polymers as additives for concrete or for other polymers
- All kind of polymers in solution or as co-polymers
- others

Further activity related to polymers and static mixing

Heat exchange

Especially with regard to high viscous components, Sulzer Chemtech has acquired a wide range of expertise in the field of exchange of thermal energy. Equipment concepts and designs derived from this expertise are characterized by short residence time and homogeneous bulk temperature. All properties ensure that the medium being subjected to the heating/cooling is processed in a careful manner, resulting in a quality product. Heat exchange equipment from Sulzer Chemtech is successfully installed in the following industries:

- Polymer Production
- Polymer Processing
- Production of synthetic fibres

Typical applications:

- Heating and Cooling of polymer and polymer-solutions.
- Mixing and removing of exothermic heat during reaction.
- Melt viscosity adjustement by temperature variation to obtain optimal process conditions.
- Cooling polymer melts before granulation to raise the viscosity.
- Cooling polymer melts before filling plants to avoid thermal damage to packing material
- Cooling polyester melts between polycondensation and spinning step.

Sulzer Chemtech has a great deal of experience designing and fabricating two different types of mixer-heat exchangers, each well suited for certain applications, mainly in the laminar field. The SMXL mixer-heat exchanger divides the main product stream in sub-streams flowing through parallel tubes, whereas the product in a SMR mixer is not split but is mixed completely over the entire diameter, making it well suited for reactions and mass transfer where mixing is important.

SMXL Static mixer-heat exchanger

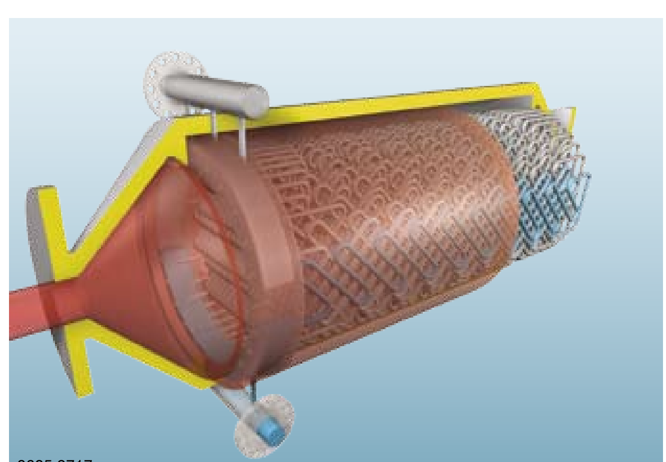
The product-conveying inner tubes are filled with static mixing elements, creating a radial mixing effect. The result is a considerably increased heat transfer and a narrow residence time distribution, making is possible to achieve a short residence time. A continuous renewal of the thermal boundary layer on the piping wall prevents thermal damage of heat sensitive products.

SMR Static mixer-heat exchanger

The SMR equipment is not only suited for applications in which mixing and heat exchange occur, but also in mass and/or reaction processes that take place simultaneously. The static mixing elements are made from tubes to create a radial mixing of the product flowing around the tubes, which the heat transfer fluid flows through. Due to the radial mixing over the entire shell diameter, the SMR is well suited for reactions where good mixing, high heat transfer, and narrow residence time distribution is important.

Multitube mixer-heat exchanger with removable SMXL mixing elements

SMR plug flow reactor and heat exchanger



Technology for expandable polystyrene (EPS)

Sulzer has developed a unique technology for the production of EPS that is based on the advantages of static mixing and continuous operation. In this versatile path of production blowing agent, e.g. pentane is continuously dosed in a bulk flow of crude polystyrene. Homogeneous mixing and temperature conditioning is taking place prior to the pelletization of product. EPS grades manufactured with Sulzer technology can be further processed as with any other commercially available EPS grade.

The fact that Sulzer's EPS technology can be applied to a wide range of polystyrene grades (HIPS, GPPS), this technology has clearly proven its industrial viability and acceptance. Some of the technology's characteristics are:

- Wide range of polystyrene grades can be converted into EPS pellets
- Flexibility in producing specialty grades e.g. colored beads, varying blowing agents, flame retardants and additives
- Virtually zero emissions such as blowing agent and waste water, resulting in high operating safety and low production cost

EPS production unit

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Sulzer Chemtech Ltd, a member of the Sulzer Corporation, with headquarters in Winterthur, Switzerland, is active in the field of process engineering and employs some 1500 persons worldwide.

Sulzer Chemtech is represented in all important industrial countries and sets standards in the field of mass transfer and static mixing with its advanced and economical solutions.

The activity program comprises:

- Process components such as trays, structured and random packings, internals for separation columns and reaction technology
- Engineering services for separation and reaction technology such as optimizing energy consumption, plant optimization studies, pre-engineering for governmental approval, basic engineering
- Separation and purification of organic chemicals by means of crystallization and membranes
- Mixing and reaction technology with static mixers
- Tower field services

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