



Static Mixing
Advanced mixing technology

It was back in 1993 when Fluitec launched its first static mixers in the market. Today, Fluitec is a reliable partner for high quality products whose know-how spans a wide range of mixing, heat transfer and reaction tasks in the chemical, petrochemical, pharmaceutical, environment and food industries.



View of the production shop – apparatus weighing up to 3.5 tons is manufactured in-house



The Fluitec management:
Daniel Altenburger (Managing Director), Silvano Andreoli (Manager Production), Alain Georg (Manager R&D), Tobias Vögeli (Manager Sales)



The Fluitec team

Fluitec static mixers

Pages 4–6

Static mixers for laminar flow

Pages 7–8

Laminar mixing applications

Pages 9–12

Static mixers for turbulent flow

Pages 13–15

Food and pharmaceutical industries

Page 16

Dosing technology

Page 17

Enquiry data sheet

Page 18

Other Fluitec products

Page 19

Static mixers are apparatus with fixed internal elements that mix the product flowing through them with the help of kinetic energy only. Since maintenance and wear are negligible, only a comparatively small space is required for installation and the apparatus is suited for a wide viscosity range, static mixers are today a popular alternative for continuous and batch processes.

Fluitec mixers are ideal for the following applications

- Mixing of pumpable liquids
- Dispersion and emulsification of components which are insoluble in each other
- Mixing of reactive liquids
- Mixing and homogenising of polymer melts
- Contacting of gas and liquid
- Mixing of gases
- Heat transfer of viscous fluids
- Laminar, uniform flow through tubes, e.g. residence time reactors

The most diverse geometries are employed to achieve a homogeneous mixture, depending on the application and the flow regime. The choice of mixer geometry is determined by the Reynolds number and the properties of the fluids to be mixed.

The mixing processes which take place in Fluitec mixers are defined, reproducible and optimised. Their high productivity and low energy consumption have a positive impact on both the capital investment and the operating costs. Industrial plants can be reliably designed on the basis of longstanding experience and the results of pilot trials. The scale-up risk is reduced to a minimum in this way.



CSE-XC/6

Mixing with static mixers

There are basically two possible types of flow: **turbulent** and **laminar**. In turbulent flow ($Re > 2400$), the fluid particles move randomly in all directions. In laminar flow ($Re < 20$), the fluid particles move in layers along straight, parallel paths. The Reynolds number is a dimensionless quantity that is defined as the ratio of inertial to viscous forces. It is the decisive parameter for the flow regime. The Reynolds number can be represented as follows referred to the diameter D or the hydraulic diameter d_h :

$$\text{Equation 1 } Re = \frac{\rho \cdot w \cdot D}{\eta} = \frac{\rho \cdot w \cdot d_h}{\varepsilon \cdot \eta}$$

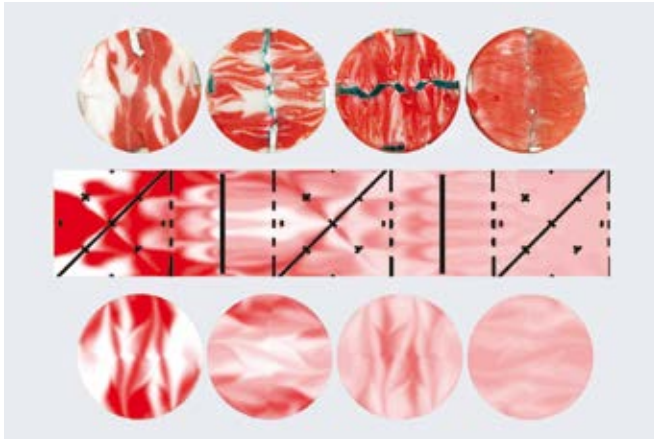
Determination of homogeneity

The mixing efficiency of static mixers in laminar flow always used to be analysed by forcing epoxy resins dyed in various colours, which had been premixed with hardener, into the mixing section and subsequently curing them. The hardened strand was cut into slices in order to investigate what goes on inside the mixer. These slices revealed a cross-section of the mixture. It could be seen that the number of layers increases rapidly with the length of the mixer; the layer thickness simultaneously decreases while the homogeneity increases. Today, the efficiency of a mixer geometry can be assessed very accurately with the help of CFD simulations. Real experiments with epoxy resin are usually only carried out in order to verify the simulation results.

The success of a mixing process can be quantified if a measure exists for the state of the mixture and this reference state can be derived from locally determined quantities (e.g. temperature, concentration, electrical conductivity, laser induced fluorescence (LIF), photometric analysis (FIP), a CFD calculation, etc. If this data is available for the cross-sectional area of flow, the mixture can be evaluated according to statistical criteria. The measured values and measuring errors generally conform to a Gaussian (normal) distribution.



CSE-W made from PTFE



Mixing efficiency assessed by means of experiments with epoxy resins (top) and CFD simulation (bottom)

Standard deviation σ

The standard deviation is a useful benchmark for the symmetrical distribution of measured values about the weighted average and is usually formed from the square root of the variance.

$$\text{Equation 2 } \sigma = \sqrt{\frac{\sum_{i=1}^n (X_i - \bar{X})^2}{n - 1}} \text{ with } \bar{X} = \frac{\sum_{i=1}^n X_i}{n}$$

If account is taken of the symmetric intervals when integrating the distribution density function, the following statement can be made regarding the distribution within an interval:

$\pm \Delta x = \pm \sigma$	68.3%
$\pm \Delta x = \pm 2 \cdot \sigma$	95.5 %
$\pm \Delta x = \pm 3 \cdot \sigma$	99.7 %

The maximum allowable deviation of individual mixture samples, referred to the mean concentration, is represented as follows:

$$\bar{x} \pm \Delta x$$

If the weighted average is referred to the concentration of a soluble mixing process, the following correlation exists with the volumetric mean:

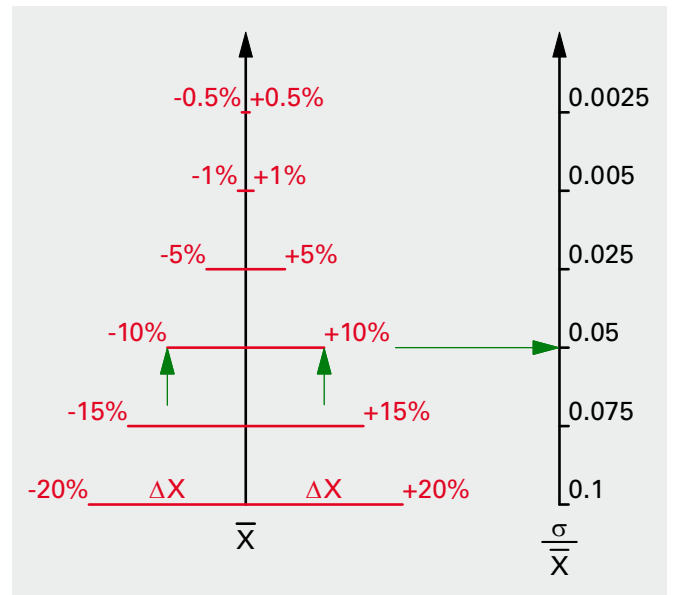
$$\text{Equation 3 } \bar{x} = \frac{\dot{V}_1}{\dot{V}_1 + \dot{V}_2}$$

Coefficient of variation $\frac{\sigma}{\bar{x}}$ (COV)

In the world of static mixing technology the coefficient of variation COV has become established as the benchmark for mixing quality. The smaller this quotient, the more homogeneous the mixture. The following quantities have an influence on the mixing quality in a homogeneous mixture:

$$\text{Equation 4 } \frac{\sigma}{\bar{x}} = f \left(Re, Fr, We, Sc, \frac{\eta_1}{\eta_2}, \dot{\gamma}, \bar{X}, \frac{L}{D}, type \right)$$

The diagram below shows the relationship between the coefficient of variation and the maximum allowable deviation from the mean concentration. 95.5% of all measured values are within the tolerance defined by this graph ($\pm \Delta X = \pm 2 \cdot \sigma$).



A mixture is normally described as homogeneous if the coefficient of variation COV is between 1 and 5% ($\frac{\sigma}{\bar{x}} = 0.01$ to 0.05).

If a mixture has 5% homogeneity, this corresponds to a coefficient of variation of 0.05, meaning that 95.5% of all measured values are within a concentration which is $\pm 10\%$ of the volumetric mean.

Pressure drop

The pressure drop must be overcome by means of conveying devices such as pumps, extruders or blowers. With Newtonian fluids, it can be described using the following equation for all flow regimes:

Equation 5

$$\Delta p = \frac{\xi}{2} \cdot \rho \cdot w^2 \cdot \frac{Le \cdot Me}{D} = Ne \cdot \rho \cdot w^2 \cdot \frac{Le \cdot Me}{D} \text{ with } w = \frac{4 \cdot \dot{V}}{\pi \cdot D^2}$$

The Newton number Ne is a parameter for determining the mixer geometry and is directly dependent on the Reynolds number.

The diagram below shows the Newton number of various static mixers as a function of the Reynolds number for their respective applications.

It can be seen that, with laminar flow, the Ne number of the new Fluitec CSE-XC/6 mixer is significantly lower than that of the conventional CSE-X/8 mixer.

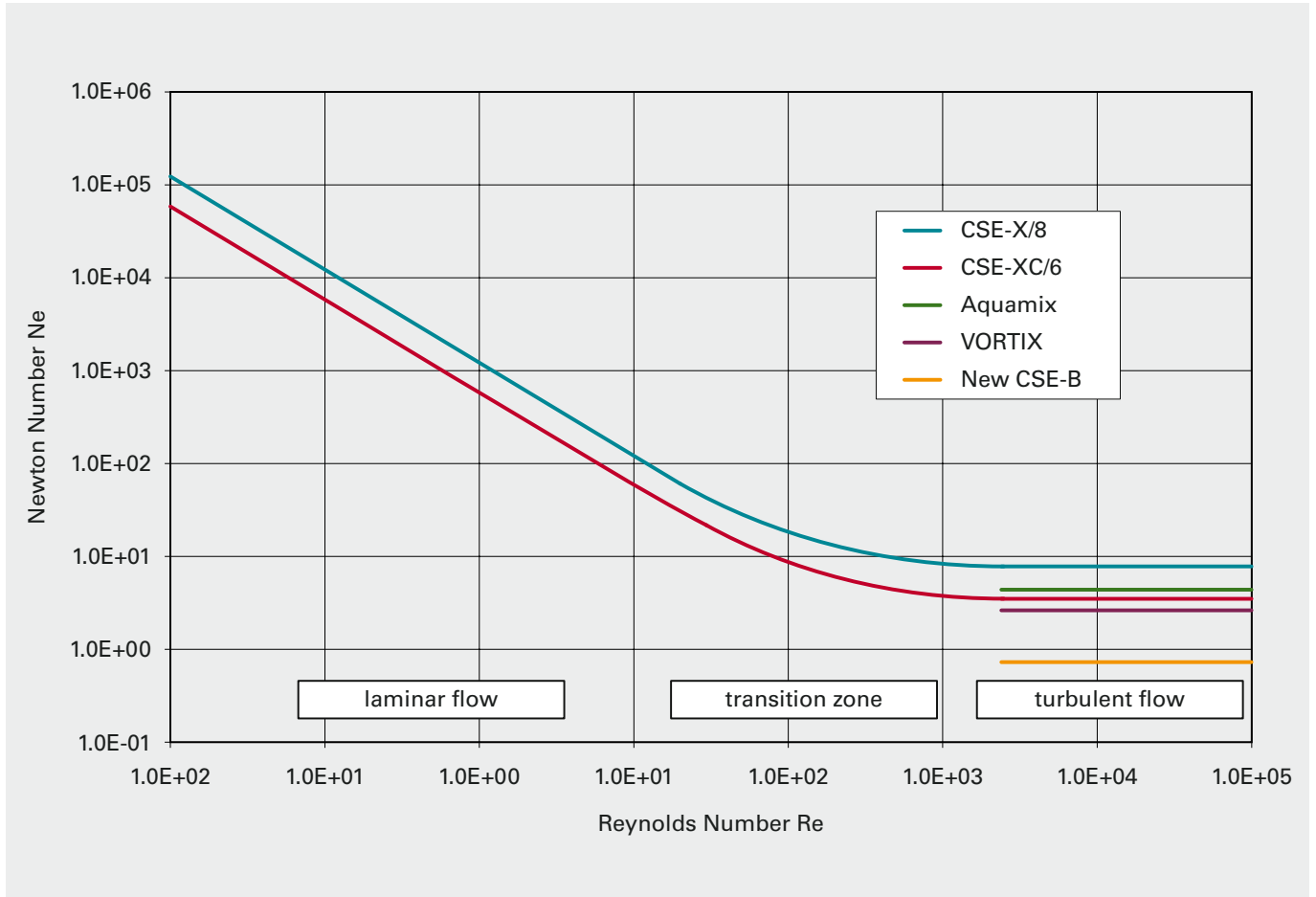
In the laminar flow regime the Newton number is inversely proportional to the Reynolds number, i.e. $NeRe = constant$. The following equation is thus used to calculate the pressure drop with laminar flow

Equation 6

$$\Delta p_l = NeRe \cdot \eta \cdot w \cdot \frac{Le \cdot Me}{D^2} = \frac{4}{\pi} \cdot NeRe \cdot \eta \cdot \frac{\dot{V} \cdot Le \cdot Me}{D^4}$$

Experience shows that the power requirements of static mixers are one order of magnitude lower than for dynamic mixers. The power consumption is directly proportional to the pressure drop and can be determined as follows

Equation 7 $P = \Delta p \cdot \dot{V}$



Pressure drop diagram for known static mixers

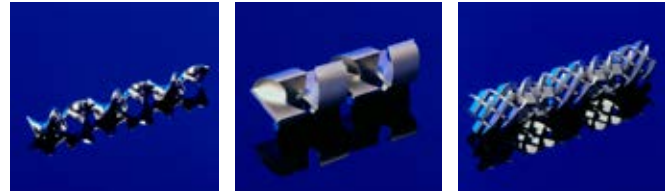
Static mixers in the laminar flow regime $Re < 20$

Laminar mixing processes are based on the repeated separation of the flow into layers, followed by redistribution and recombination parallel to the flow direction. The number of layers, and hence the homogeneity, increases with each additional mixing element. A homogeneous mixture is primarily achieved by diffusion as a result of layer growth. The design and length of the mixer vary according to the mixing process. Fluitec's speciality is an efficient, energy saving mixer for each specific mixing task.

The mixing quality of a soluble mixing process is largely dependent on the volume flow and viscosity ratios. It can also be influenced by diffusion, the shear rate, the residence time and the Froude number.

X mixers have emerged during the last few years as by far the most powerful and most popular of all known basic geometries, namely CSE-W, CSE and CSE-X. Thanks to laser welding technology, Fluitec can meanwhile build the CSE-X with any desired diameter – from very small to very large – and using a wide range of materials.

Fluitec is continuing to develop and optimise the above mixer geometries. The new «CSE-XC/6» mixer, which combines a small pressure drop with high mixing efficiency, the «mikromakro®» mixer technology and the «CSE-X-DS high performance mixer» are just a few recent examples. From mixing and gasification through emulsification and homogenisation to mixing processes



Basic geometry of the CSE-W helical mixer and the CSE and CSE-X mixers


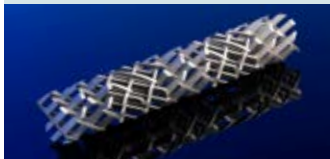


involving extreme viscosity ratios, Fluitec CSE-X® mixers have been the technology of choice for several decades now.

Development of the new CSE-XC/6

Over a period of many years, various attempts were made to improve the mixing intensity of the CSE-X mixer. The engineers at Fluitec considered the mixing processes in the static mixer from a different angle for this purpose. The question they asked themselves was «Is layer growth in the CSE-X mixer determined by the number of bars or is it the open ducts between the bars that are responsible?»

If the open ducts are the culprit when it comes to layer growth, they concluded, one remedy might be to reduce the number of bars from 8 to 6 and at the same time open the wall area of the mixer tube. The mixing element would thus have the same number of ducts (openings) but would be easier to manufacture and the mixing efficiency ought to remain constant.

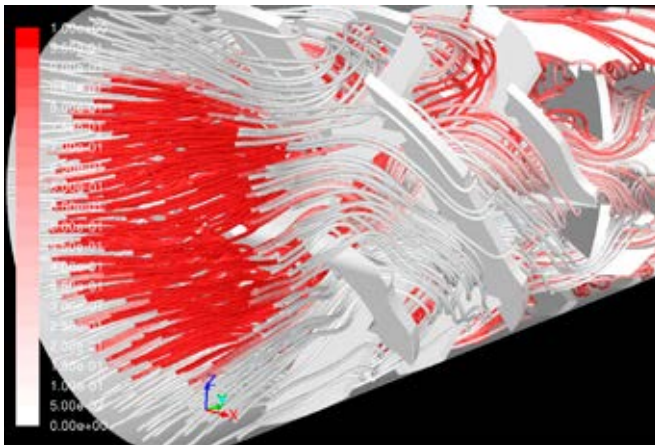
Fluitec uses various types of mixer inspired by the basic geometry of the CSE-X

<p>CSE-XC/6</p>  <p>The new CSE-XC/6 is a more advanced version of the CSE-X/8. It reduces the pressure drop by up to 50% without compromising mixing efficiency and can also mix high or low-viscosity fluids without any problems. This new mixer model has a narrower residence time distribution than the CSE-X/8.</p>	<p>CSE-X/8</p>  <p>The CSE-X/8 was the number one universal mixer for many years. In the meantime, it has been largely superseded by the new CSE-X/6 owing to its relatively high energy consumption. However, its geometry sometimes has advantages and it therefore remains the system of choice in certain applications.</p>	<p>mikromakro®</p>  <p>mikromakro® mixing could be described as the targeted use of static mixers with different geometries and diameters. The macro mixer normally serves to achieve good pre-distribution of the product prior to fine distribution in the micro mixer.</p>	<p>CSE-X-DS</p>  <p>The CSE-X-DS high performance mixer is an X mixer with additional bars. These improve the mixing efficiency, residence time distribution and variable concentration range, though at the expense of higher energy consumption. This mixer type is therefore only used to meet special requirements.</p>
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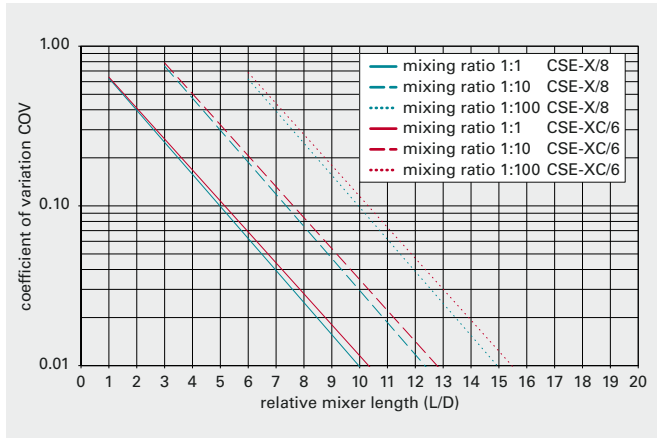
Systematic investigations

Systematic investigations carried out in the search for answers to this question resulted in several novel mixer types. The mixing properties of the different versions were studied both when using polymer melts and in mixing processes with high viscosity ratios.

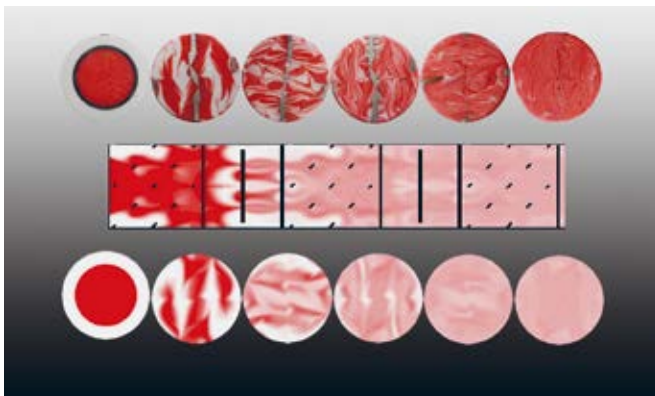
The efficiency of the new mixer geometry is comparable to that of the CSE-X/8. The suspicion that layer growth is determined not by the number of bars but by the number of open ducts has been confirmed in the meantime.



Investigation using CFD simulation



Coefficients of variation of the CSE-XC/6 and CSE-X/8 compared



Mixing of two epoxy resins in the new CSE-X (top) and CFD calculation (bottom). The cut views along the mixing section show the rapid growth of the layers.

Opening the wall area is conducive to efficient mixing and the residence time range is relatively narrow. No wall effects have so far been observed in the CSE-X/6 mixer.

High and low-viscosity mixing processes

Mixing trials with a viscosity ratio greater than 1:1000 can generally be described as problematic. In the past, only the CSE-X/8 mixer was capable of mastering this kind of challenge. Mixing trials with the new CSE-XC/6 have demonstrated very impressively that the new mixer, too, excels at even the most complex mixing processes. In other words, the CSE-X/6 provides clearly superior performance compared to conventional X mixer types.

The advantages of the new CSE-X/6 mixer can be summed up simply as follows:

Same mixing efficiency:

- Approx. 50% smaller pressure drop across the mixer.

Same pressure drop:

- One diameter smaller mixer design.
- The residence time is approximately 40% shorter.

mikromakro® for extreme mixing processes

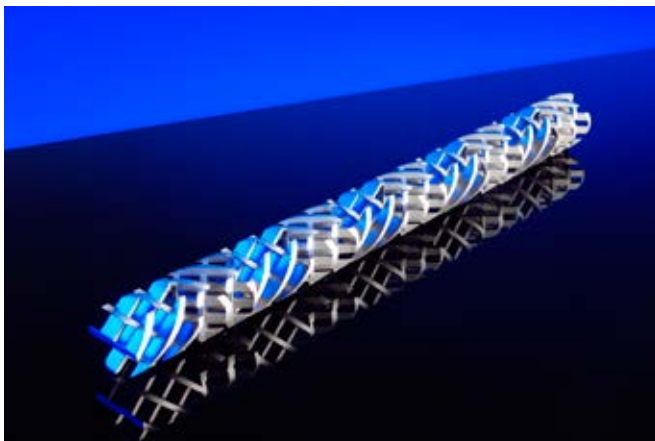
mikromakro technology

mikromakro® mixing could be described as the targeted use of static mixers with different geometries and diameters. The macro mixer normally serves to achieve good pre-distribution of the product prior to fine distribution in the micro mixer. For years now, the Fluitec CSE-X® mixer has been used in applications with very exacting requirements. Most CSE-X® mixers have between 4 and 12 bars. The mixer design and the number of bars depend on the mixing process and the mixer diameter.

The mikromakro® technology improves the mixing quality of even the most complex mixing processes. For example, mixing elements with more bars at the end of a mixer increase the potential for diffusive mixing, whereas the targeted use of different diameters enables better mixing quality owing to the higher shear rate.



mikromakro® mixer for a high pressure application (polymer)



CSE-X/4 and CSE-X/8 welded together to form a mikromakro® mixer bar

CSE-X for low throughputs

Laser welded elements

CSE-X mixing elements with small diameters have been employed over a period of many years in a wide range of applications, mainly in small plants in the chemical, plastics, food and pharmaceutical industries. Today, Fluitec can supply mixing elements with a diameter of just 4.6 mm and Ra 0.4 surface quality thanks to special laser production processes and finishing techniques.



Mixing elements $D_e = 4.6$ to 10 mm



Laser welding

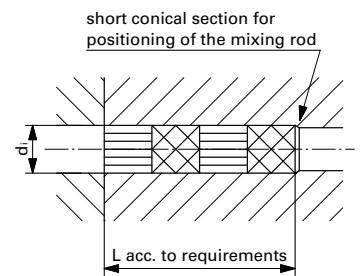
Cast elements

Cast mixing elements in standard dimensions are available from stock at attractive prices because it is possible to manufacture them in large quantities. Fluitec has an extensive range of cast mixing elements, so that cast mixers can be shipped without delay for many applications. An unfinished cast surface is sufficient for the majority of mixing processes.

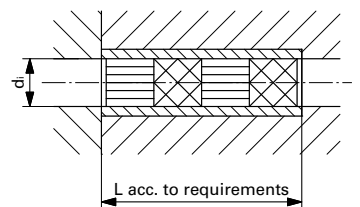
Installation types

Mixer bars can be provided for various installation types.

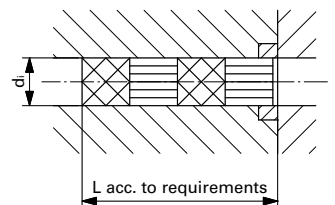
Inserted



Sleeve design



Supporting ring

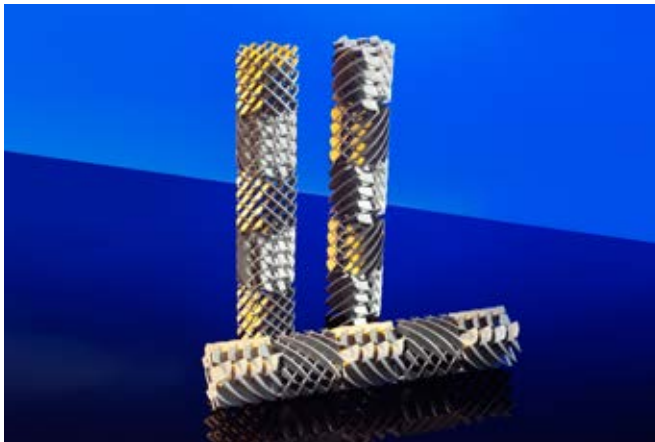


CSE-X-DS high performance mixer

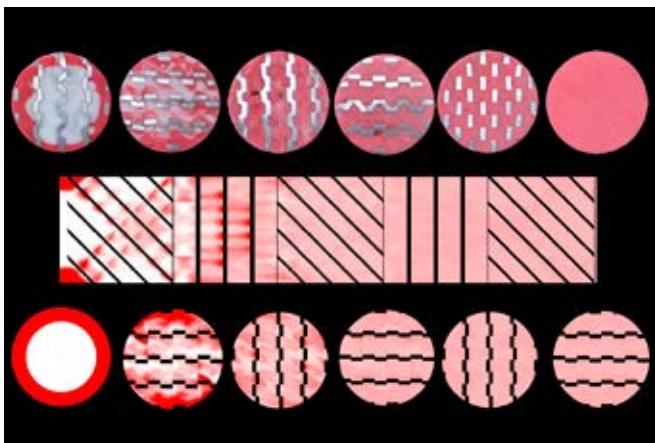
A high performance mixer is an X-mixer with additional bars. The high performance mixer is ideal whenever very high mixing efficiencies or very good residence time properties which cannot be realised using conventional static mixers are stipulated.

CSE-X-DS high performance mixers are used in the following applications to meet specific requirements:

- Short mixing length / limited space available
- Viscosity ratios from 1 to 1'000'000 and concentrations of up to 50%
- Narrow residence time distribution
- Very slow flow velocities in residence time reactors



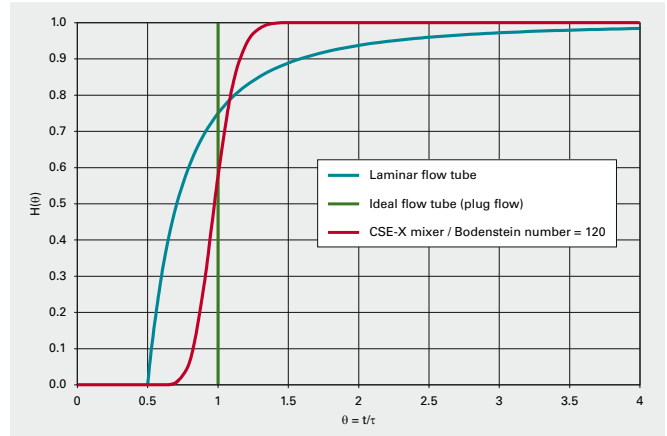
CSE-X/4-DS and CSE-X/8-DS



Mixing efficiency of the high performance mixer (experiments with epoxy resin and CFD simulation). A homogeneous mixture is achieved after just a very short mixing length.

CSE-X as a residence time mixer

Fluitec CSE-X® mixers are notable for their high mixing efficiency and short installation length. Numerous studies have confirmed the CSE-X® mixer's excellent residence time distribution.



Cumulative residence time curve

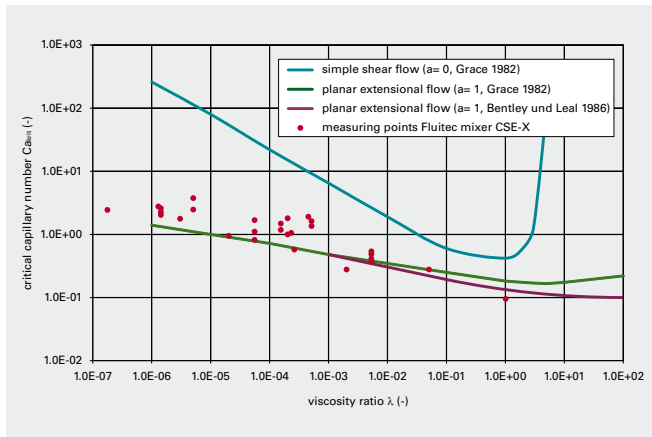
It can be seen from the diagram that CSE-X® mixers come very close to an ideal plug flow regime. This is an indication of good self-cleanability, which is especially important in reactions or hygienic applications. The studies were carried out using glucose syrup with various viscosities from 1 to 500 Pas. Whereas in the empty tube, dye additives still adhered to the wall, they were no longer visible in the CSE-X® mixers.

Dispersion in laminar flow

When dispersive mixing occurs in the laminar flow regime, the resulting droplet size d_T is determined by the shear and elongational components in the flow. Finer droplets can be achieved if elongational flow components are introduced into the flow field compared to just shear components. Provided a suitable mixer geometry is chosen, the amount of energy which is required for the droplet break-up process can be reduced. The ratio of viscous to interfacial tension force is decisive for the droplet break-up process:

$$\text{Equation 8 } Ca = \frac{G \cdot d_r \cdot \eta_c}{2 \cdot \sigma} = \frac{\text{force of tenacity}}{\text{interfacial tension force}}$$

Droplet break-up only occurs after a defined time t_z if $Ca \geq Ca_{crit}$ where η_c stands for continuous viscosity and G is the deformation rate.

Critical capillary number Ca_{crit}

The graph shows the influence of the viscosity ratio on the critical capillary number Ca for droplet break-up in simple shear flow ($a = 0$) as well as in planar elongational flow ($a = 1$).

The flow parameter a , which describes the elongational component of the total deformation rate, can be represented as follows.

$$\text{Equation 9} \quad a = \frac{\dot{\epsilon}}{|\dot{\epsilon}| + |\dot{\gamma}|}$$

It is clear from the measured values that CSE-X static mixers have a high elongational component. A correspondingly lower energy consumption is thus necessary to achieve the droplet size dT . Static mixers have an a value from 0.2 to 0.7 depending on the mixer geometry.

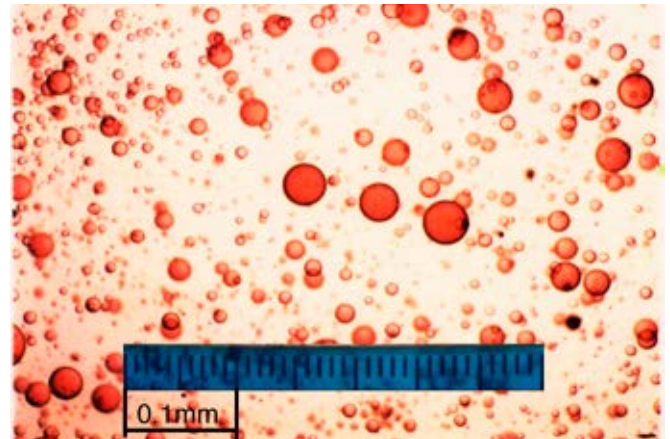
Droplet break-up time t_z

With static mixers, the droplet break-up time in dispersion processes depends mainly on the nature of the break up. The break-up time t_z is influenced by the viscosity ratio γ and the dosing technology. A large initial droplet size can have negative impacts on the droplet spectrum, especially in conjunction with a high viscosity ratio γ , leading to a longer droplet break-up time and / or a longer mixer. Special dosing modules with a flow measurement function, a pump and a special injection nozzle have been developed for CSE-X mixers for this reason.

Typical applications

Within the practical limits, static mixers for dispersion and emulsification are suited for the following applications

- Mixing of partially soluble liquids (miscibility gap)
- Contacting and heating of polymer prior to flash evaporation (water, nitrogen, etc.)

Sample of a glucose dispersion with 5% additive (viscosity ratio $\gamma = 5 \times 10^{-4}$)

- Incorporation and emulsification of insoluble additives prior to pelletising (mineral oil, lubricants, etc.)
- Dispersion of gas or liquids upstream of a spray dryer
- Washing unwanted aromas or additives out of viscous liquids
- Dispersion and cooling for reactive mass transfer processes
- Incorporation and emulsification of blowing and nucleating agents for foams (e.g. pentane, air, nitrogen, etc.)
- Establishment of uniform cell structures in foams (re-dispersion and homogenisation)
- Manufacture of mousses
- Manufacture of creams
- Dispersion during extraction processes

Fluitec melt mixers

For many years now, static mixers have been used to homogenise polymer melts, ideally in combination with melt pumps. Reduced pulsations and improved thermal homogeneity are leading to a significantly higher quality of the melt and much higher contouring accuracy of the final products.

The new Fluitec CSE-XB/4 and CSE-XC/6 melt mixers are short, with a length of just 2D to 4D, and have a much smaller pressure drop than conventional melt mixers despite their very high mixing efficiency. The extra-rigid design enables high-viscosity polymers to be processed at high throughputs. The compact and rugged construction allows operating pressures of up to 500 bar and pressure drops of 100 bar.

The homogeneous melt temperature, constant discharge volume and homogeneous viscosity distribution which can be achieved using a Fluitec melt mixer are immediately evident. The staining quality is simultaneously improved, so that the costs for dye are reduced by up to 25%. Thanks to the homogeneous melt, it is possible to reduce the melt temperature, leading to further quality improvements in the extruded product.



Melt mixers in sleeve design

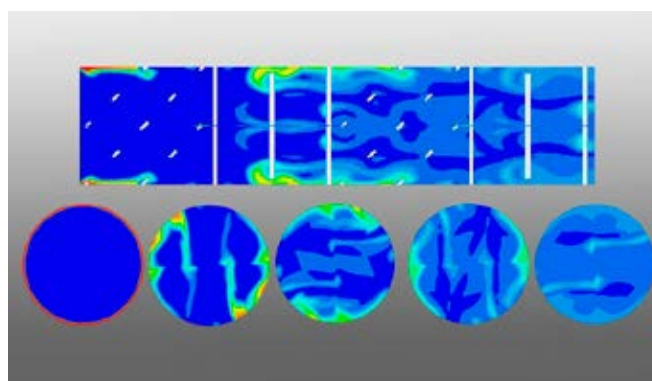


Melt pump with the new CSE-XC/6 melt mixer

Fluitec fibre modules

CSE-X/4 mixer for the man-made fibre industry

A homogeneous melt upstream of the spinnerets is one of the key requirements for the production of high quality man-made fibres. The novel CSE-XC/4 fibre modules developed to tackle this problem are setting new benchmarks in the industry. The new fibre modules combine high mixing efficiency with a very small pressure drop. Compared to the helical mixers which are traditionally used in the manufacture of man-made fibres, the new CSE-X/4 mixing element reduces the pressure drop by around 30 to 40% for the same mixing performance. Even with significantly better performance, the pressure drop is still around 15 to 20% smaller. Furthermore, this mixer reduces possible deposits on the wall areas to a minimum, so that there is no longer any need for complex soldering. The CSE-X/4 mixer unites a very narrow residence time range with excellent self-cleanability.



Simulation visualising «incorporation of the surface layer» with a CSE-XC/4 mixer across 4 elements. The diagram clearly shows that most of the surface layer (red at the mixer inlet) has been renewed after 3D; it has been completely removed after 4D. The wall area is flushed much more efficiently with the CSE-XC/4 than with conventional static mixers because the bars at the tube wall are open.



Cut views of epoxy resin mixtures produced under comparable conditions. The section on the left is of a CSE-X/8 mixture after L/D = 3. The middle section was obtained using a helical mixer after six mixing elements (L/D = 9.6). The section on the right shows a CSE-XC/4 mixture after L/D = 4.

High-tech, energy efficient and affordable

The Fluitec «Aquamix» and «VORTIX» mixers are nowadays standard solutions for use in the turbulent flow regime.

Static mixers can significantly reduce the time required for mixing processes when the flow through the tube is turbulent. Special mixing elements are used here to form the vortex. Mixing and homogenisation take place in the downstream mixer tube. Two mixer designs have become established during the last few years: the Aquamix slide-in mixer for installation in existing tubes and the VORTIX housing-type mixer, which can be supplied in several different versions and materials (metal or plastic).



5% blue additive is dosed upstream of an Aquamix ($Re = 18000$)

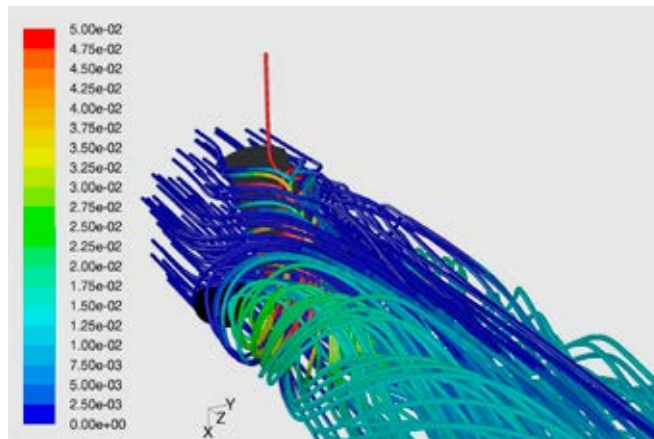
Aquamix slide-in mixer

The Aquamix is the latest addition to the slide-in mixer family (clamped between two flanges of a pipe). The CSE-F® and CSE-B® mixers, the Aquamix's predecessors developed by Fluitec back in 1997 in close cooperation with Zurich University of Applied Sciences, were among the first commercially available static mixers to be clamped between two flanges in this way. The CSE-F and CSE-B are only rarely used today, however, because the Aquamix is more compact, more efficient and above all cheaper. The Aquamix produces several defined vortices and therefore mixes rapidly with only a small pressure drop. The mixer can be clamped very easily between two pipe flanges. With its compact design, the Aquamix can be used in almost any piping system.

VORTIX in-line mixer

The desire for a static mixer with a low energy consumption and consistently good mixing performance led to the development of the VORTIX in-line mixer. Two standard versions of the VORTIX are available: the compact VORTIX with a very small pressure drop and the slightly longer VORTIX-T for more complex mixing processes.

The VORTIX and VORTIX-T in-line mixers can be made from either metal materials or plastic (PP, PE, PVDF or PVC).



CFD calculation of a VORTIX turbulent mixer



VORTIX-T made from PP

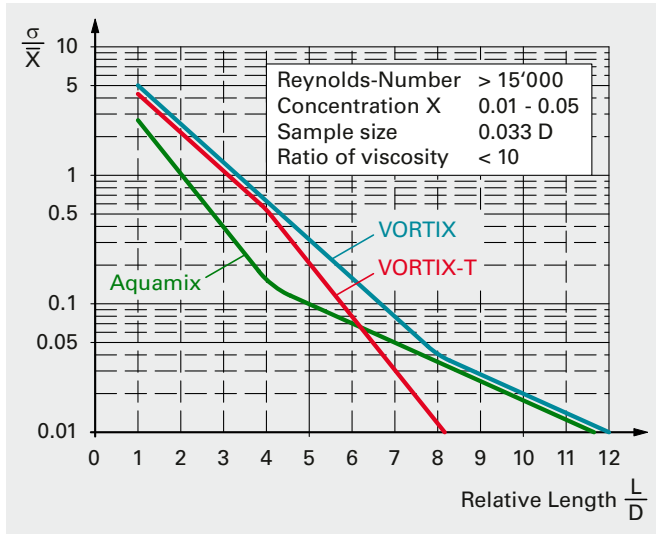
Mixing performance and pressure drop

The high mixing performance of the Aquamix and the VORTIX is based on two contrarily rotating vortices. These vortices stretch over the whole cross-sectional area and ensure excellent mixing efficiency. Homogeneity is normally expressed by the coefficient of variation (refer to page 5 for an explanation). A coefficient of variation < 0.05 is assessed as homogeneous. Full performance of the mixer is achieved at flow velocities $> 0.3 \text{ m s}^{-1}$.

In the Aquamix, the additive is dosed before the flange connection. For low additive concentrations of $< 5\%$, the injection nozzle must be mounted concentrically. Otherwise, a normal T-piece can be fitted at a distance of 2 to 5D (diameters of the tube) upstream of the mixer.

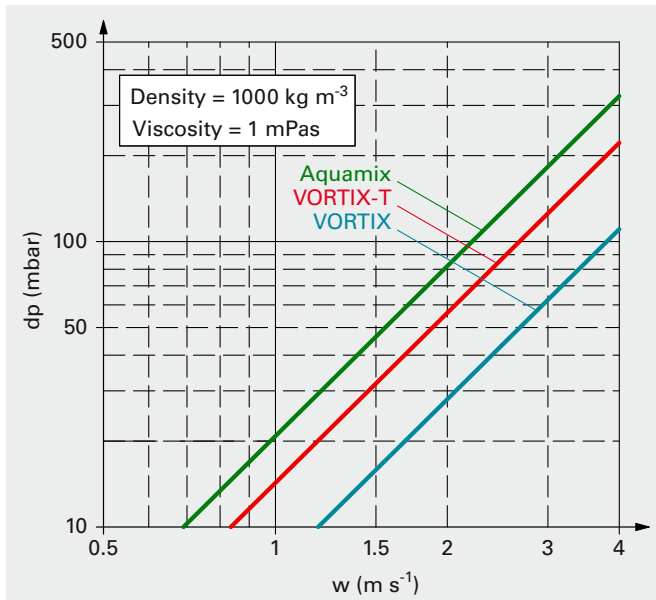
The additive is introduced into the VORTIX mixer via the side port. This port is arranged such that the additive is optimally incorporated throughout the mixer. The injec-

tion nozzle must be precisely adjusted to the amount of additive in order to achieve optimum mixing results.



Coefficient of variation for a typical turbulent mixture

The representation of the coefficient of variation as a function of the relative mixing length shows that measuring points such as temperature sensors or pH probes must be installed at a minimum distance of 10D from the mixing element.



Pressure drop

The Aquamix and VORTIX were developed as static mixers with a small pressure drop, so that the piping can now be designed for velocities of up to 4 m s⁻¹.

Liquid gasification with static mixers

Mass transfer

In liquid gasification processes, the mass transfer is influenced on the one hand by the system's coalescence behaviour and on the other by Henry's law.

With static mixers, high gas transfer rates are achieved not only by the concentration gradient, which is normally fixed, and by intensive contacting of the two phases but also by the formation of small gas bubbles with a large specific interfacial area.

$$\text{Equation 10 } \dot{n} = k_L a \cdot (c^* - c)$$

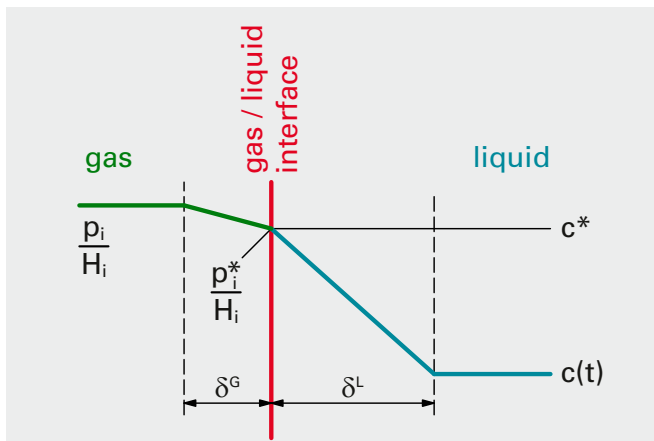
The expression $k_L a$ is a combination of two factors:

- k_L = mass transfer limiting resistance due to the liquid film
- a = specific interfacial area (A/V) of the gas which is introduced

The two-film model

According to the two film model, the much lower mass transfer resistance in the gas film k_G is negligible (refer to the diagram below). Henry's law states that the concentration c_i of a dissolved gas is proportional to its partial pressure p_i in the gas phase [equation 13]. This relationship is described using the Henry's law constant H_i , which is substance-specific:

$$\text{Equation 11 } p_i = H_i \cdot c_i$$

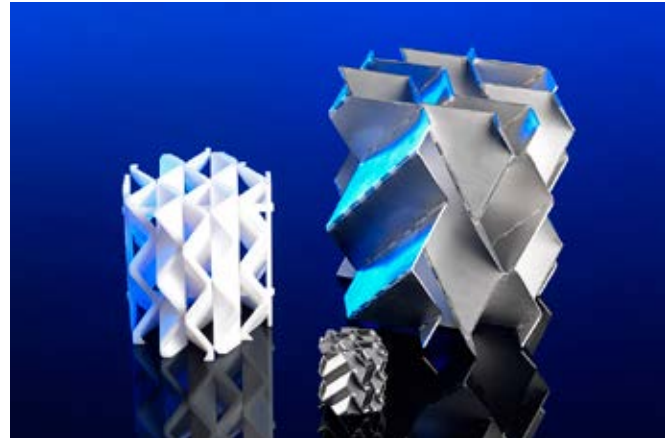


Representation of the concentration gradient around a gas / liquid interface according to the two-film theory and Henry's law

The gas transfer rate is in direct proportion to the mass transfer coefficient due to the liquid film k_L , the specific interfacial area a and the concentration difference $\Delta c = c^* - c_L$. Whereas Δc may be influenced by physical parameters such as pressure, temperature and concentration, the term $k_L a$ is a result of the hydrodynamics caused by the reactor used. The term a is generally

unknown here and like k_L is itself a function of the material and process-specific parameters. Both parameters are difficult to quantify in practice, which is why, as the product, they usually represent the target variable during the mass transfer.

Today, it is above all the CSE-X and CSE-V geometries which are used for dispersion processes and thus for liquid gasification.



CSE-V mixing elements

The ideal length of the static mixer depends on the operating pressure, the temperature, the installation position, the phase component of the gas to be dissolved and the desired concentration.

It is determined by means of the following function:

$$\text{Equation 10 } L = \frac{w}{k_L a} \cdot \ln \frac{C^* - C_{in}}{C^* - C_{out}}$$

Fluitec mixers made of stainless steel or Hastelloy have been used throughout the process industry for many years. Fluitec specialises in high quality mixing elements, which is why we are able to meet even the very high – and highly individual – quality requirements for static mixers in sterile processes or food industry applications without any problems.

High on hygiene, low on maintenance

Fluitec CSE-W, CSE-X and Aquamix mixers destined for the food and pharmaceutical industries can be manufactured with electropolished surfaces and the required tube fittings, so that they are suitable for use in sterile environments. However, the requirements relating to the quality of the mixer tend to vary from one application to another and are influenced by factors like process safety, quality assurance, GMP, CIP / SIP, economic efficiency, etc.

Since both CSE-W and CSE-X mixers provide excellent self-cleanability, absolute sterility with no dead spots is guaranteed provided the apparatus can be emptied and the welds are expertly made.



Aquamix for food applications



CSE-X/4 for sterile applications

The following tube fittings can be used together with Fluitec mixers:

- Dairy fittings acc. to DIN 11851
- Clamp fittings (Tri-clamp)
- BioConnect couplings (Neumo)
- BBS couplings
- Aseptic tube connections (Südmo)
- Small flange connections acc. to DIN 11850
- Other fittings on request

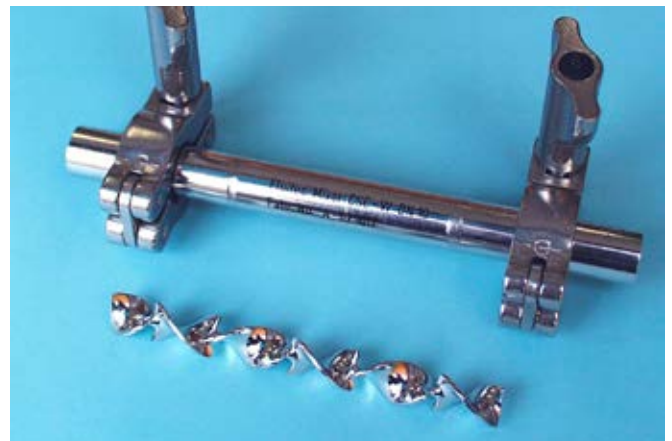
Increased quality requirements

After selecting the type of connection, the next step is to define the welding method and the surface treatment. A great many requirements have to be satisfied here. However, the overarching regulation is the Pressure Equipment Directive (PED) 2014/68/EU.

The housings can be either orbitally or manually welded. Thanks to our in-house laser welding line, we are in a position to weld mixing elements with a diameter of just 4.6 mm.

Both mixing elements and housings can be supplied with mechanically polished or electropolished surfaces. $R_a < 0.8 \mu\text{m}$ is the norm for surface roughnesses; finer surfaces can be achieved using special manufacturing processes.

We employ 1.4571, 1.4404, 1.4435, 1.4435 BN2 or other high-alloy materials. The ferrite content, surface roughness and various other parameters can be measured and documented for quality assurance purposes.



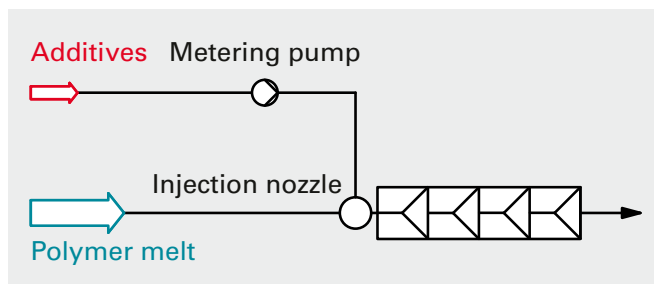
CSE-W mixer (DN10) with electropolished surfaces, a Tri-clamp fitting and a ferrite content of $< 0.5\%$ in the welds

Dosing technology for static mixers

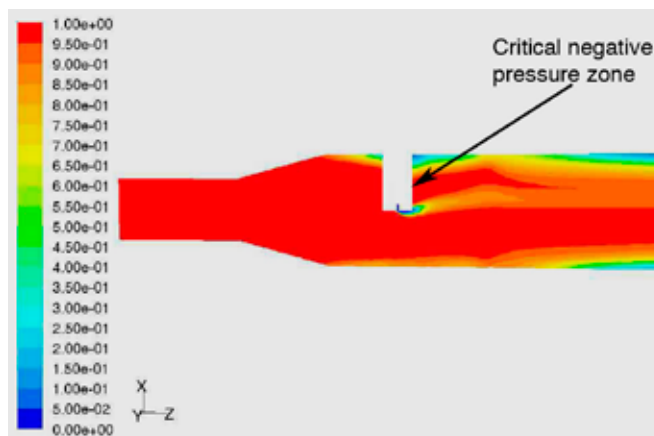
The dosing technology for static mixers ensures the controlled and simultaneous incorporation of the additive and main streams into a static mixer. Since static mixers are generally designed with only low back-mixing, the components have to be dosed constantly over time.

The following aspects must be taken into account when planning a static mixing system:

- It must be possible to monitor the additive and main streams.
- The mixing quality is influenced by the position and geometry of the injection nozzle.
- Pulsations impact on mixing quality and suitable measures must be implemented to control them.
- An efficient cleaning concept is especially important in static mixing systems. The properties of the fluids to be mixed must be considered along with the mixer's installation position.



Fluitec LV dosing of polymers



Transient calculation of an injection nozzle

Optimised injection nozzle

The mixing quality is determined by the position and geometry of the injection nozzle regardless of the flow regime. It is generally best to dose the additive concentrically, directly upstream of the static mixer. If this is not possible, the mixing efficiency of anything between two and four mixing elements is wasted.

Critical vacuum zones, which firstly result in dead spots and secondly influence the additive stream, may be created depending on the flow. Fluitec has been using transient CFD calculations to investigate the injection nozzles for static mixers since 2001.

The injection nozzle has been optimised in several ways during this period:

- Concentric dosing of the additive stream
- Fewer dead spots
- Use of the vacuum zone for controlled pre-distribution of the additive streams
- Use of additional plates as mechanical protection for the static mixer



Injection nozzle for polymer mixers with mechanical protection against polymer plugging



Inquiry data sheet Fluitec Static Mixer

Contact:

Company: Phone:
 Name: Fax:
 Street: E-Mail:
 ZIP/Town: Country:

Inquiry:

Project / Inquiry-Nr:
 Inquiry requested until:
 Only budget quotation: Yes No

Process Data:

	Unit:	Main stream	Side stream 1	Side stream 2	Side stream 3
Name fluid:	[-]	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Flow minimal:	[m ³ h ⁻¹]	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Flow normal:	[m ³ h ⁻¹]	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Flow maximal:	[m ³ h ⁻¹]	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Density:	[kg m ⁻³]	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Viscosity:	[mPas]	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Temperature:	[°C]	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Classification fluid: <small>(acc. 2014/68/EU)</small>	1:gaseous 2:liquid	<input type="checkbox"/> 1 <input type="checkbox"/> 2	<input type="checkbox"/> 1 <input type="checkbox"/> 2	<input type="checkbox"/> 1 <input type="checkbox"/> 2	<input type="checkbox"/> 1 <input type="checkbox"/> 2
	h:hazardous n:not hazardous	<input type="checkbox"/> h <input type="checkbox"/> n	<input type="checkbox"/> h <input type="checkbox"/> n	<input type="checkbox"/> h <input type="checkbox"/> n	<input type="checkbox"/> h <input type="checkbox"/> n

Are the fluids mixable? Yes No → Surface tension: mN m⁻¹ Maximal droplet size: mm

Homogeneity as standard deviation in relation to mean value [σ√X]: < %

Maximal allowed pressure drop: bar (Description of the mixture)

Mechanical Data:

Planned nominal diameter of the pipe DN Different possible: Yes No

Notice:

Standard configuration

Design code: AD2000 ASME

Connections: Flange EN1092 Flange ANSI Thread connection Free tube end

Injection nozzle: No Yes → Flange Thread connection Free tube end

Mixing elements: Not removable Removable Only elements, no housing

Material: 316 L / 316 Ti 304 / 304 L 1.4435 Hastelloy C22
 Duplex 2205 904 L PE / PP Carbon steel / PTFE

Mixing pipe: Max. allowed pressure: bar Max. allowed temperature: °C

Heating jacket: No Yes → Max. allowed pressure: bar Max. allowed temperature: °C

Increased Requirements: (for example for food- and pharma-industry)

Surfaces: No specifications Ra<1.6 μm Ra< μm Electropolished

Mixing elements: No specifications Gap free, as possible Edges rounded

Remarks:

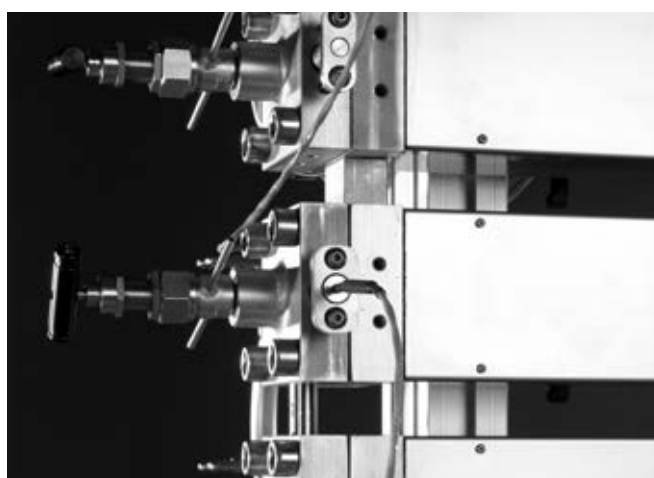
Documentation: (if required)

- Drawing / Parts list List of material certificates
- Welding specifications Fabrication control plan
-



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