fluitec
mixing + reaction solutions

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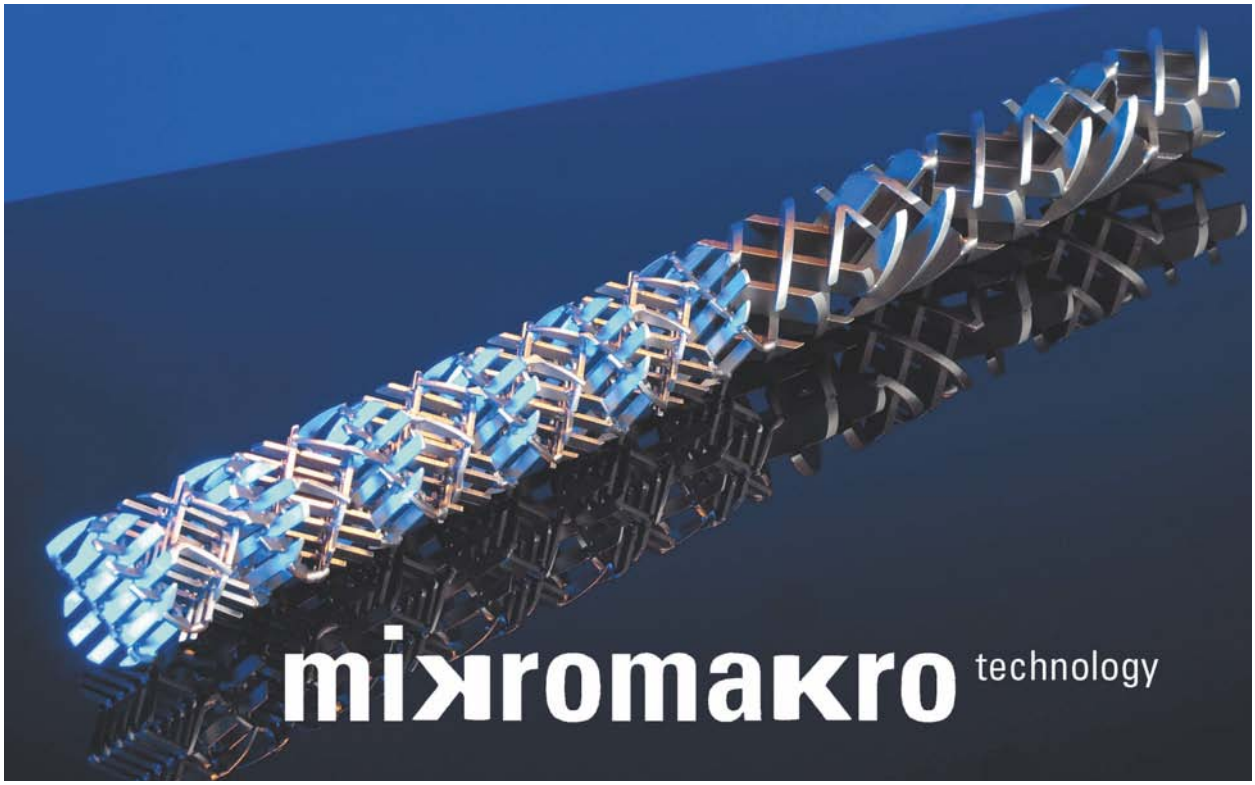
mikromakro technology **for sophisticated mixing tasks at**

laminar flow condition

mikromakro®-mixing means the systematic use of static mixers of different geometries and sizes. Basically, a rough but well distributed pre-homogenisation is achieved in the makro-mixer, while a perfect homogenisation is realised in the following mikro-mixer. Fluitec CSE-X® mixers are well established and proved for industrial mixing processes of highest demands. Standard CSE-X® mixers consist out of 4 to 12 bars. The final design, the arrangement and the sizes of mikromakro® mixing elements, however, are customized to its individual application.



mikromakro® mixer

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At laminar flow, the well established geometry of the CSE-X mixer is the perfect solution for intense radial mixing. This mixer type finds its fields of applications in a wide area. Applying the mikromakro® technology, different designs, arrangements and sizes of the CSE-X are used in order to improve the mixing efficiency while decreasing the energy consumption.

A CSE-X mixing element itself is built of several single mixing bars, attached to each other in a 90° angle. The typical *L*/*D* ratio of a single mixing element is 0.5 or 1. To get a complete mixing rod, several of such mixing elements are attached to each other, again in a 90° angle. The number of mixing bars is depending on the mixing task and on the diameter of the mixing elements. Normally used mixing elements consist of 4, 6, 8, 10 or 12 bars.

Mixing performance of mikromakro® mixers

Mixing at laminar flow of $Re < 20$ is mainly achieved by forced convection and based on the generation of multiple layers. The quality of a mixture of soluble components is in a strong function of the

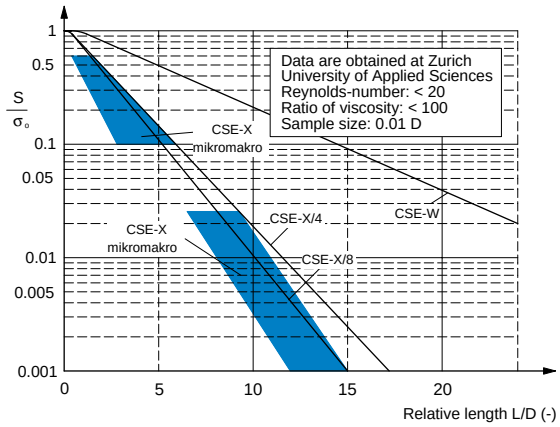

Fig. 2: Relative standard deviation

flow rates and of the ratio of viscosities of the pure components. Fig. 2 shows the degree of homogeneity, expressed as the relative standard deviation, in function of the mixer length *L*/*D*. Parameters are different Fluitec mixer types. Further factors such as diffusion, shear rate, residence time and *Froude*-number can influence the mixing quality additionally. For the most difficult mixing tasks, the application of the mikromakro® technology can be a very effective, or even the only way to achieve a perfect homogeneity at a passable pressure drop. An increased number of mixing bars of the final mixing elements, for example, is improving the potential of diffusive mixing significantly. The systematic use of different diameters on the other hand, is influencing the homogeneity by the well defined and controlled shear forces.

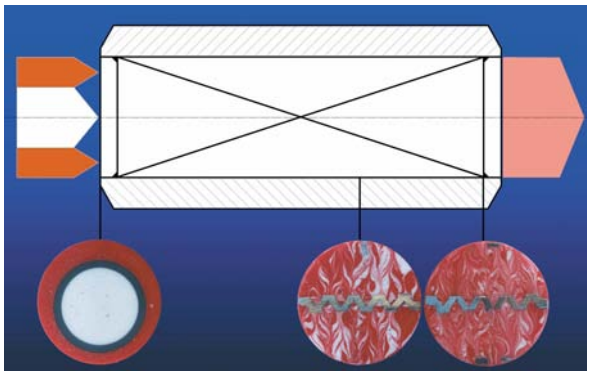

Fig. 3: Mixing performance of a mikromakro® mixer 3D-module for the fibre industry

Pressure drop of mikromakro® mixers

Pressure drop at laminar flow rate can be calculated as follows:

$$\Delta p_L = Ne\,Re \cdot \eta \cdot w \cdot \frac{L}{D^2} \qquad \text{Eq. 1}$$

The *NeRe*-number and the relative length *L*/*D* are often used to compare the pressure drops of static mixers of similar nominal width and similar homogeneity. The drag coefficient at same nominal width and same homogeneity can thereby be calculated as follows:

Drag coefficient = *NeRe* x relative length.

Comparison of CSE-X mixers at relative standard deviation of 0.01:

CSE-X/4 mixer DN 50 (4 bars):
relative length *L*/*D* = 13, *NeRe* = ca. 750
drag coefficient = 13 x 750 = 9'750

CSE-X/8 mixer DN 50 (8 bars):
relative length *L*/*D* = 10, *NeRe* = ca. 1'200
drag coefficient = 10 x 1'200 = 12'000

Using the CSE-X/4 mixer with 4 bars, about 3 elements more are required to achieve a mixing quality which is comparable to the CSE-X/8 with 8 bars. Pressure drop of the CSE-X/4 mixer, however, is reduced significantly by about 20%. This is even more surprisingly, since the hydraulic diameters are about equal.

Following the cognitions above, it is clear that the mikromakro® technology serves several drastic advantages such as:

- reduction of the pressure drop at constant relative length
- reduction of the mixer length at minimal increased pressure drop
- avoiding of incomplete mixing by sedimentation and stable layers due to differences in the specific weight of the components

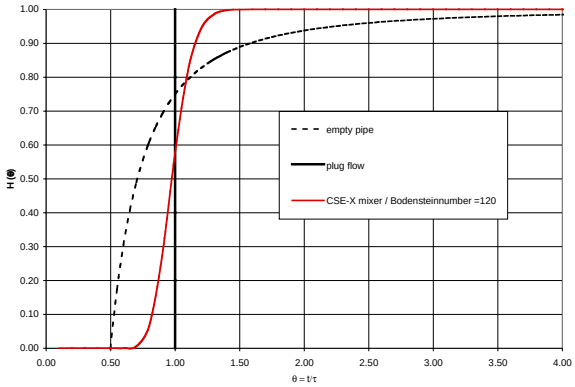

Fig. 4: Residence time distribution in a mixer

Residence time distribution of CSE-X® mixer

All Fluitec mixers type CSE-X are characterised by the intense mixing performance at a short installation length. Numerous investigations made clear, that the residence time distribution is outstanding narrow. Fig. 4 visualizes the almost ideal plug flow in a CSE-X mixer.

Also the self cleaning efficiency is unrivalled - a very important factor in the food- and pharma-sector. Among others, investigations were conducted using glucose syrup of a viscosity of 1 Pas to 500 Pas. The dye additives in the CSE-X mixer were already completely removed, while they were sticking at the wall of the empty tube f or a much longer time.

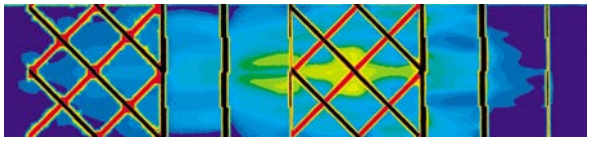

Fig. 5: CFD calculations of the CSE-X® mixer