A new mixing device based on elongational flows.

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The recently built device, later called RMX (elongational flow Reactor and MiXer), is schematically represented in the figure below. The material to be mixed is alternately pushed from one cylindrical chamber to the other through a central static mixing element by two reciprocally moving pistons. The standard mixing element is composed of a small diameter cylindrical die. The convergent and divergent elongational flows at the entrance and exit of the die were shown to contribute significantly to dispersive mixing. The following original features characterize the RMX device:

1 Feeding of components

In addition to the central channel which connects the chambers (mixing channel), the mixing element is fitted with three additional channels, one for the feeding of the components to be mixed, one for the outlet of the mixed material, and a third one (not represented in the figure) which connects one of the chambers to a pressure transducer. The feeding channel can be connected to a feeding unit which allows melting pellets and feeding the obtained melt into the mixer. It can also be connected to a three-ways sieve and a pump which allows direct feeding of low viscosity liquids. It is also possible to feed sequentially several components: for instance two mutually reactive components can be independently fed into the mixer by transferring the first component in the opposite chamber before introducing the second one.

2 Mixing

In this step, both the feeding and outlet channels are closed. The volume of material inside the mixer is adjusted by the initial positions of the pistons and can be varied in the range [10-100 cm^3]. The pistons are hydraulically driven by a servovalve at controlled speed in the range [0.18 – 180 mm/s] which for 3cm diameter pistons corresponds to volume flow rates in the range [0,125 – 125 cm^3/s]. The maximum pressure in the upstream chamber is limited by the power of the hydraulic station and is therefore a function of the flow rate. Typically at the highest flow rate, the upstream pressure can reach around 200 bars. A mixing sequence is defined by the piston speed (or flow rate) and the number of cycles, and an experiment can be composed of several consecutive sequences at different flow rates. The pressure in one of the chambers is continuously measured during the mixing sequence by a pressure transducer connected to this chamber through the mixing element. Since the flow is reversed during each cycle, only one pressure transducer is required to measure the pressure drop between the two chambers: As a matter of fact, the transducer measures alternately the upstream and the downstream pressure at each flow reversal, so that the pressure drop between the chambers is merely the difference of both pressure measurements.

3 Outlet of the mixed material

At the end of the mixing step, all material is first pushed into the right chamber connected with the outlet channel. The outlet channel can be used to take samples at the end of an experiment (or even during an experiment between two mixing sequences), or can be connected to a mould. During moulding, the left piston is in a fixed position and the right piston pushes the material into the mould. During this step the device is working like an injection machine. Unlike for other types of microcompounders (Twin-screw or Brabender type), no additional step (like recovering the melt, placing it into a mould, reheating and moulding) is therefore required to mould specimens of specified shape after mixing.

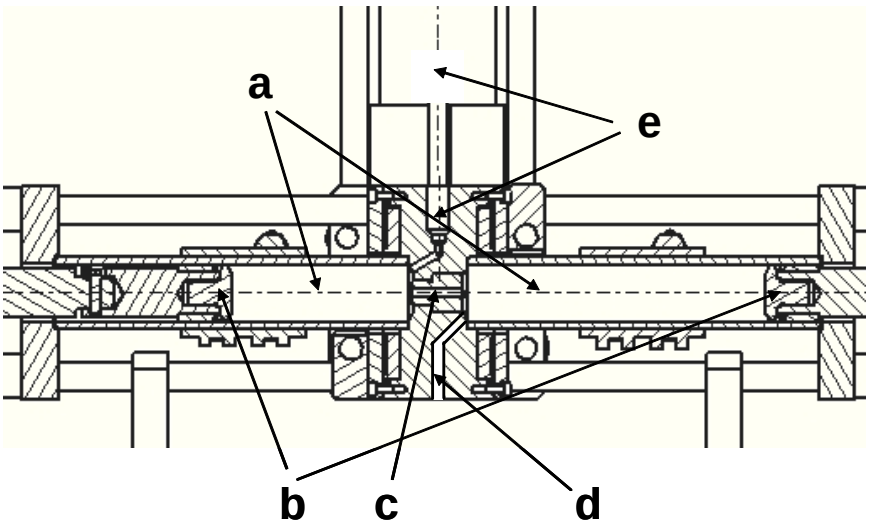
It is important to notice that the mixing element is removable and therefore the shape and diameter of the mixing channel can be easily varied and different L/D ratios between 1.5 and 5 were tested.

On the other hand, it should be pointed out that the mixing volume can be made pressure-tight to liquids and gases by appropriate seals between the pistons and the chambers, thus allowing to work under controlled atmosphere and high pressures since a counter-pressure can be applied in the downstream chamber. RMX has thus a broad field of potential applications. It can in particular be operated as a stirred pressurized batch reactor, either for polymer modification with volatile reactants or even for polymerization. Moreover, the design of the mixing element allows continuous feeding and outlet, which opens the possibility of use as a stirred continuous reactor.

Finally, by adapting an intrumented die on the outlet channel, the device can be operated as a pre-shear capillary rheometer.

The first results obtained for polymer blends are summarized in a recent paper (G. Bouchet, C. Loux, M. Bouquey & R. Muller, *Journal of Applied Polymer Science* **119**, 482-490 (2011).

Several versions of the device (hydraulic, electric, pneumatic) adapted to a broad range of viscosities as well as different options of feeding systems and moulds, are commercially available (http://www.scamex.fr/fr/melangeur/melangeur_reacteur.html).



Schematic drawing of the mixing device. a: mixing chambers, b: pistons, c: mixing element, d: feeding unit and feeding channel, e: outlet channel (sampling or molding).

Abstract:
A new lab-scale mixing device based on an original concept was built and tested. This device presents important technical features like tightness to liquids and gases, the possibility of direct moulding of specimens after mixing and easy handling of reactive systems. Compared to existing laboratory mixers, the flow in the mixer is characterized by a high contribution of elongational flow.