Microstructural de-mixing in periodic flows

Citation for published version (APA):
Introduction
Key mechanism of laminar fluid mixing is stretching and folding. Here stretching in a “journal bearing flow” (JBF) is investigated.

Extended mapping method
The flow domain is subdivided into a small cells and the mixture described by concentrations in these cells. Transport of material (rheologically identical fluids with negligible surface tension) between cells during a (large) time step is given by a pre-computed sparse mapping matrix. Each cell receives from donor cells both concentration and interfaces (Fig. 1).

Fig. 1 Mapping of concentration and microstructure
The microstructure is described by the area tensor $A$ (Fig. 2) The interfacial area per unit volume is given by $\text{tr}A = s_v$. The area tensor is mapped and transformed under finite deformation [1].

\[ A_{ij} = \frac{1}{V_{cell}} \int_S n_i n_j dS, \]

$n$ is the a unit normal to the increment of interfacial area $dS$.

Fig. 2 Definition of area tensor

Stretching in periodic flows
Mapping method was used to model microstructure development in chaotic flows. The flow between alternatively rotating eccentric cylinders [2] is examined. The typical flow patterns are shown in Fig. 3.

Fig. 3 Streamlines for rotating inner or outer cylinder

After few periods a self-similar distribution and asymptotic orientation of interfaces is achieved. Based on this pattern, locally averaged stretching experienced by interfaces during one period of the flow was determined:

Fig. 4 Logarithm of one-period interface stretching factor
In certain regions the interfaces are strongly contracted (Fig. 4), because orientation pattern created by the flow itself does not favour stretching there. Such microstructural demixing zones, where interfaces shrink and striations thicken, are likely to appear where the folds of material layers are formed:

Fig. 5 Contours of demixing zones plotted on typical mixture pattern created after 5 periods
Since stretching and folding is a basic mechanism of laminar mixing, microstructural demixing zones should be its essential feature. They were detected in different examined flows.

Conclusions
Zones of microstructural demixing are found in a periodic laminar mixing flow. Such zones may contribute to complex stretching dynamics and irregularity of striation thickness distribution.

References: