Supplementary Information

Coflowing aqueous and oil-based ferrofluid streams exposed to a magnetic field

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S1. Properties of the liquids used in the experiments

The properties of the aqueous glycerol (glycerol+DI water):

Fluid	DI water: Glycerol %(v/v)	Density ($\mathrm{kg\ m^{-3}}$)	Viscosity ($\mathrm{mPa\ s}$)
Aqueous glycerol	1:1	1139	6.43
	2:1	1099	2.96
	9:1	1025	1.52

The properties of oil-based ferrofluid:

Fluid	Concentration %(v/v)	Density ($\mathrm{kg\ m^{-3}}$)	Viscosity ($\mathrm{mPa\ s}$)
Ferrofluid	2%	892	28.8
	5%	1098	36.1

The interfacial tension between the different fluid combinations:

DI water: Glycerol	Oil-based Ferrofluid	IFT ($\mathrm{mN\ m^{-1}}$)
1:1	2%	27.3
2:1	2%	24.1
9:1	2%	19.7
1:1	5%	13.4
2:1	5%	15.5
9:1	5%	23.8

S2. Calculation of the timescales

The transition between the different flow regimes can also be explained in terms of the relevant timescales: magnetic pinching timescale, which we define as $t_{mp} \sim (\gamma W / \nu \mu_0 H^2)$ and advection timescale, $t_{ad} \sim (W/U_2)$. The advection timescale t_{ad} is calculated from the channel width W and the average flow velocity of the aqueous phase, U_2. The magnetophoretic timescale is estimated using the values of the interfacial tension (γ), channel width W, kinematic viscosity of the aqueous phase (ν), magnetic permeability of free space (μ_0), and magnetic field intensity (H).

Case I:

For smaller $\mathrm{Bo_m} = 20$ and $\mathrm{Ca_r} = 2.6$, we find that the magnetic pinching timescale is much longer than the advection timescale, $\mathrm{t_{mp}} > \mathrm{t_{ad}}$. The liquid properties and operating conditions for calculating the $\mathrm{t_{mp}}$ and $\mathrm{t_{ad}}$ in this regime are given as follows: interfacial tension, $\gamma = 24.1\ \mathrm{mN/m}$, channel width, $\mathrm{W} = 300\ \mu\mathrm{m}$, the average flow velocity of the aqueous phase, $\mathrm{U_2} = 0.02\ \mathrm{m/s}$, kinematic viscosity of the aqueous phase, $\nu = 3 \times 10^{-6}\ \mathrm{m^2/s}$, magnetic permeability of free space, $\mu_0 = 4\pi \times 10^{-7}\ \mathrm{N/A^2}$, and magnetic field intensity, $\mathrm{H} = 2950\ \mathrm{A/m}$.

We calculate the $\mathrm{t_{mp}} \sim 0.223\ \mathrm{s}$ and $\mathrm{t_{ad}} \sim 0.015\ \mathrm{s}$.

Case II:

For smaller $Bo_m = 30$ but a higher $Ca_r = 7$, we get a magnetic pinching timescale which is of the same order as that of the advection timescale, $t_{mp} \sim t_{ad}$. The liquid properties and operating conditions for calculating the $\mathrm{t_{mp}}$ and $\mathrm{t_{ad}}$ in this regime are given as follows: interfacial tension, $\gamma = 24.1\ \mathrm{mN/m}$, channel width, $\mathrm{W} = 300\ \mu\mathrm{m}$, the average flow velocity of the aqueous phase, $\mathrm{U_2} = 0.01\ \mathrm{m/s}$, kinematic viscosity of the aqueous phase, $\nu = 3 \times 10^{-6}\ \mathrm{m^2/s}$, magnetic permeability of free space, $\mu_0 = 4\pi \times 10^{-7}\ \mathrm{N/A^2}$, and magnetic field intensity, $\mathrm{H} = 7521\ \mathrm{A/m}$.

We calculate the $\mathrm{t_{mp}} \sim 0.034\ \mathrm{s}$ and $\mathrm{t_{ad}} \sim 0.030\ \mathrm{s}$.

Case III:

At a higher Bo_m and Ca_r, we find that the magnetic pinching timescale is smaller than the advection timescale, $t_{mp} < t_{ad}$. The liquid properties and operating conditions for calculating the $\mathrm{t_{mp}}$ and $\mathrm{t_{ad}}$ in this regime are given as follows: interfacial tension, $\gamma = 24.1\ \mathrm{mN/m}$, channel width, $\mathrm{W} = 300\ \mu\mathrm{m}$, the average flow velocity of the aqueous phase, $\mathrm{U_2} = 0.005\ \mathrm{m/s}$, kinematic viscosity of the aqueous phase, $\nu = 3 \times 10^{-6}\ \mathrm{m^2/s}$, magnetic permeability of free space, $\mu_0 = 4\pi \times 10^{-7}\ \mathrm{N/A^2}$, and magnetic field intensity, $\mathrm{H} = 15545\ \mathrm{A/m}$.

We calculate the $\mathrm{t_{mp}} \sim 0.008\ \mathrm{s}$ and $\mathrm{t_{ad}} \sim 0.060\ \mathrm{s}$.