# Pairing and group dynamics in parallel-wall channels

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# Pairing and group dynamics in parallel-wall channels

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## Introduction

Miniaturization is an ongoing trend for various equipment, in particular for fluid analysis systems. Due to various flow-focusing devices, a typical morphology in these microfluidic devices is a train of drops or particles (Fig. 1). Hydrodynamic interactions between the drops/particles and with the walls will govern the resulting behavior.

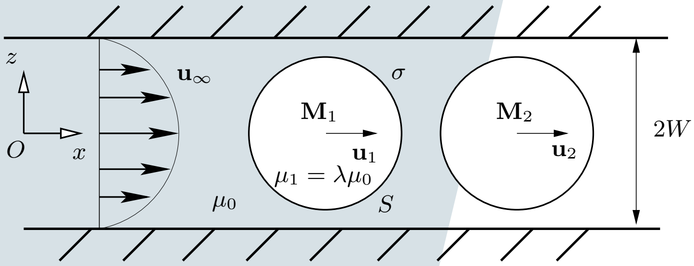


**Figure 1** *A train of (two) drops with radius $R$ between parallel walls. All drops have a mass center $\mathbf{M}_i$, and a migration velocity $\mathbf{u}_i$.*

## Objective

Investigate the collective dynamics of trains consisting of either deformable drops or rigid particles, and focus on the influence of the deformability and initial configuration.

## Methods & assumptions

- Two-wall boundary integral method for drops [1].
- Stokesian dynamics techniques for particles [2].
- Confinement ratio $R/W$ fixed at 5/6.
- Viscosity ratio $\lambda = 1$ for drops.
- Mass center placed exactly half way between the walls.

## Results

### Pairs

Particles traveling in pairs have no relative migration. Drops, due to their deformability (proportional to the capillary number Ca), move to a fixed separation (Fig. 2a); the far-field velocity scales as Ca$\Delta x^{-3}$ (Fig. 2b). One other interesting feature in channels is that isolated drops and particles move faster than groups due to collective drag reduction of pairs/trains.

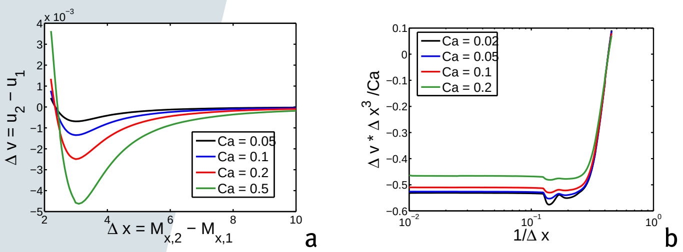


**Figure 2** *(a) Relative velocity of the leading drop to the trailing drop as function of mass center distance, (b) rescaled far-field velocity.*

### Trains

Trains of both drops and particles show pairing at the back, while the front drop moves away from the train (Fig. 3). As both drops and particles show this behavior (Fig. 4), this has to be attributed to the collective drag reduction.

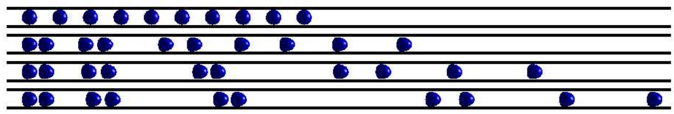

**Figure 3** *Images in time of a drop train with Ca $= 0.2$, $\Delta x_0 = 4R$.*

The deformation of drops influences the dynamics at longer time scales, as the drops in a pair move to a fixed separation, while particles keep their separation. The non-uniform intra-pair distance gives different velocities for particle pairs (Fig. 4a). Placing drops with a high Ca initially close together may further complicate matters (Fig. 4b).

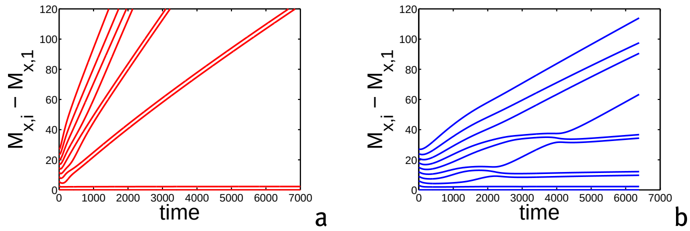


**Figure 4** *Location of mass centers relative to the first in time: (a) particle train with $\Delta x_0 = 3R$, (b) drop train with $\Delta x_0 = 3R$ and Ca $= 0.2$.*

### Lateral displacements

If one, or more, drops or particles are displaced in $y$-direction, the dynamics are influenced as well. For example, particle displacements grow in time (Fig. 5).

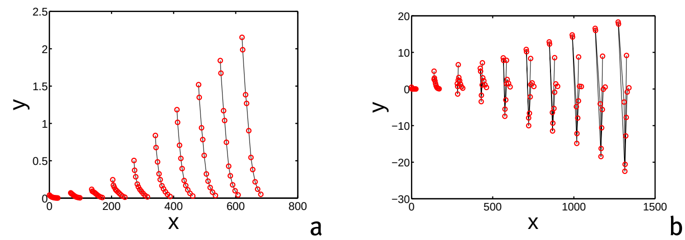


**Figure 5** *Location of mass centers of particle trains at various moments in time: (a) small exponential decaying displacement in the $y$-direction, (b) only the first particle displaced with $\Delta y = 0.5R$.*

## Conclusions

- Trains of drops and particles show interesting behavior in parallel-wall channels.
- On short time scales, pairing occurs.
- At longer time scales, drop pairs move to a fixed separation, and this influences the migration.
- Lateral displacement show fascinating dynamics.

*References:*

[1] Janssen & Anderson, Phys. Fluids, 19, 043602, 2007
[2] Bhattacharya *et al.*, J. Comp. Phys., 212, 718, 2006

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