Swinging and tumbling of multicomponent vesicles in flow – Supplementary materials

Prerna Gera[1], David Salac[2], and Saverio Spagnolie[1,3]
[1] *Department of Mathematics, University of Wisconsin–Madison, Madison, Wisconsin 53706, USA*
[2] *Department of Mechanical Engineering, University of Buffalo, Buffalo, NY, USA*
[3] *Department of Chemical & Biological Engineering,*
University of Wisconsin-Madison, Madison, WI 53711, USA

I. MOVIE CAPTIONS

- Movie M1: Vesicle dynamics with bending stiffness variation in spatial mode M=2. Beyond a critical magnitude of variation the elongated axis transitions from swinging to tumbling.

- Movie M2: As in Movie M1, but with a smaller enclosed area.

- Movie M3: As in Movies M1-M2, with yet smaller enclosed area.

- Movie M4: Vesicles in a shear flow with different spatial modes of material property variation. The M=2 mode most strongly interacts with the deformation imposed by the background shear flow. The magnitude of the variation is just large enough for the case with two domains (M=2) to tumble.

- Movie M5: As in Movie M3, but with increased variation in the bending stiffnesses. The swinging amplitudes of vesicles with even numbers of domains (M even) are increasing.

- Movie M6: As in Movies M1-M2, with yet smaller enclosed area.

II. MOVIE PARAMETERS

Movie	Mode(s)	ε	$\bar{\kappa}\mathcal{C}^{-1}$
M1	2	0.05	{0.3, 0.87, 0.871, 2}
M2	2	0.1	{0.3, 0.698, 0.699, 2}
M3	2	0.15	{0.3, 0.7, 1, 2}
M4	{1,2,...,8}	0.1	0.75
M5	{1,2,...,8}	0.1	2
M6	{1,2,...,8}	0.1	4

III. DESCRIPTION OF MOVIES M1–M3

Visualizations of the different types of observed dynamics. Let $(\varepsilon, \bar{\kappa}\mathcal{C}^{-1})$ denote the amount of deformation and the variation in the bending rigidity. The results can be grouped thusly:

- Swinging: $(0.05, 0.3)$, $(0.05, 0.87)$, $(0.1, 0.3)$, $(0.1, 0.698)$

- Phase-Lagging: $(0.05, 0.871)$, $(0.1, 0.699)$, $(0.15, 0.7)$, $(0.15, 1)$

- Tumbling: $(0.05, 2.0)$, $(0.1, 2.0)$, $(0.15, 2)$

The systems $(0.05, 0.87)$ and $(0.1, 0.698)$ are just below the critical $\bar{\kappa}\mathcal{C}^{-1}$ value required for tumbling, while $(0.05, 0.871)$ and $(0.1, 0.699)$ are just above it. Just below the critical $\bar{\kappa}\mathcal{C}^{-1}$ value the tip of the vesicle dips below horizontal but does not continue due to the phase-lagging of the high-bending rigidity region (in red). Just above the critical value the vesicle begins to tumble, with the surface domains sliding between the tip and the edge, never making a full rotation around the permiter. As $\bar{\kappa}\mathcal{C}^{-1}$ further increases the high-bending rigidity regions become locked away from the tips due to the large bending energy.

IV. DESCRIPTION OF MOVIES M4–M6

Visualization of how the mode (the number of domains) influences the dynamics of a vesicle with $\varepsilon = 0.1$ for Movie M4: $\bar{\kappa}\mathcal{C}^{-1} = 0.7$, Movie M5: $\bar{\kappa}\mathcal{C}^{-1} = 2$, and Movie M6: $\bar{\kappa}\mathcal{C}^{-1} = 4$. A value of $\bar{\kappa}\mathcal{C}^{-1} = 0.7$ is just larger than the critical value necessary for the mode-2 vesicle to tumble, see Movie M2. In general only even modes are observed to tumble, with higher modes requiring a higher bending rigidity difference. Due to the non-symmetric nature of the odd modes, the membrane deformation is no longer symmetric.