FIG. 5: (color online) (a) Phase diagram for the bilayer coupling model in the $(v, \Delta a)$ parameter space, adapted from Ref. [43]. The dashed line indicates a continuous transition, while the solid line indicates a limit shape. Both lines are shown schematically in order to exaggerate the difference between the shape cycles. The two elliptical cycles considered enclose the same area in phase space, but one crosses the transition line. (b) Swimming velocity of the vesicle as a function of time, for the two shape cycles shown in (a). The squares denote the continuously varying velocity of the lower cycle in (a), which is similar to what we observed for the spontaneous curvature model. The circles correspond to the upper cycle in (a) and involves a shape transition, and there is a portion of the cycle during which the vesicle has zero swimming velocity due to fore-aft symmetry.

motion during this quarter-cycle is forward. From $t = 1/4$ to $t = 1/2$, the "lobes" of the vesicle move downwards, propelling the vesicle upwards, albeit at a decreasing rate. This portion of the motion resembles the characteristic undulatory shape of a jellyfish, albeit one at zero Reynolds number. Between $t = 1/2$ and $t = 3/4$, the vesicle deflates and the lobes begin to move upwards again, with the material points of the lobes moving almost completely tangentially to the surface. This creates a vortex dipole at the lobes, leading to the stagnation point that can be seen in the figure. Finally, in the last quarter cycle, the vesicle encloses itself and returns to the starting position. We calculate a mean swimming velocity of $\langle U \rangle = -0.048$, and a hydrodynamic efficiency of $\eta_H = 0.6\%$.

The upper elliptical cycle of Fig. 5a, with shapes illustrated in Fig. 7, follows the parameter path $v(t) = 0.775 + 0.075 \sin(2\pi t)$, $\Delta a(t) = -0.14 \cos(2\pi t) + 0.89$, which lies above the continuous stomatocyte-oblate phase transition line from $t \approx 0.45$ to $t \approx 0.55$. During this portion of the cycle the vesicle has exactly zero swimming velocity due to the fore/aft symmetry of oblate shapes.