Electronic Supplementary Material (ESI) for Lab on a Chip.

Mechanical analysis related to the acceleration actuated Binary platform

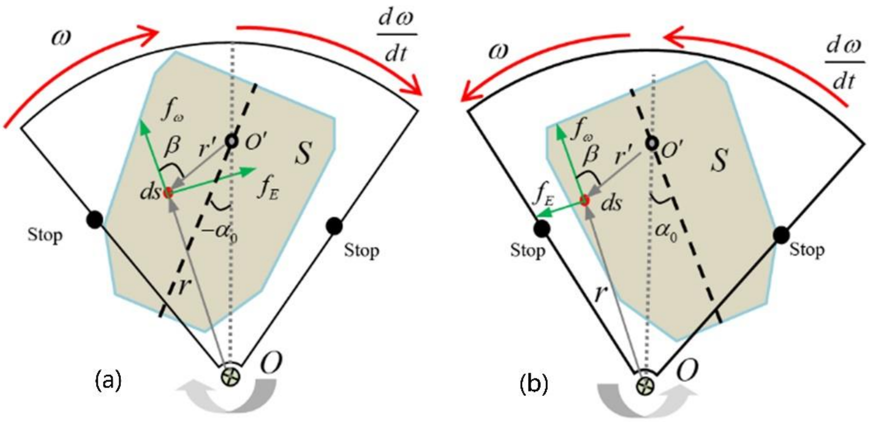

Figure 1 Binary states on centrifugal microfluidic platform, which is actuated by acceleration. The forces experienced by each mass element (*ds*) include centrifugal force and Euler force. (a), Clockwise accelerator will switch the chip to LEFT state; (b), Anti-clockwise accelerator will switch the chip to RIGHT state.

Analytically, if the disc is rotating with an angular accelerator or decelerator, Euler force should be incorporated, which is expressed as

$$\vec{\mathbf{f}}_E = -\rho r \frac{d\vec{\boldsymbol{\omega}}}{dt} \qquad (1)$$

The Euler force in the azimuth direction is opposite to the angular accelerator. If the element is moving relative to the disc, (here, with angular velocity ω' about secondary axis O') the Coriolis force should be expressed as

$$\vec{\mathbf{f}}_C = -\rho\vec{\boldsymbol{\omega}} \times (\vec{\boldsymbol{\omega}}' \times \vec{r}') \qquad (2)$$

which is in the direction of r' , the distance from O' to the field element, meaning that the extension of Coriolis force go through the secondary axis O'. Therefore, Coriolis force has no contribution to the rotation of chip relative to the disc. Because the whole chip is fixed at the secondary axis O', the chip could rotate around O' just like a ‘pendulum’, and the α is the angle swinging. All the force including centrifugal force and Euler force will give an angular moment and make the ‘pendulum’ rotating about the axis O'. Since $\boldsymbol{f}_\omega$ is a conservative force, it is possible to define a potential element dU for element ds

$$dU = -\rho_s r^2 \omega^2 / 2 \cdot ds \qquad (3)$$

ρ_s is the surface mass density of the chip. After integral over the whole chip, the potential $U(\omega, \alpha)$ is a function of

ω and α. When α equals zero, the total potential of the chip gets maximum, and it is an unstable equilibrium point. The stop nut is a restriction for the angle of swinging, and provides it maximum value α_0, where the potential minimizes. According to Figure 1, the total angular moment could be expressed as an area integral:

$$\begin{aligned}\mathbf{P} &= \mathbf{P}_E - \mathbf{P}_\omega = -\int_S \rho_s (f_\omega r' \sin\beta + f_E r' \cos\beta) ds \\ &= \int_S \rho_s r' r (\frac{d\omega}{dt}\cos\beta - \omega^2 \sin\beta) ds \\ &= \frac{d\omega}{dt}\int_S \rho_s r' r \cos\beta \cdot ds - \omega^2 \int_S \rho_s r' r \sin\beta \cdot ds\end{aligned} \quad (4)$$

The integral takes over the total area S of the chip; β, the angle between r and r', is a function of element position. Then total angular moment is also a function of ω and α, which gets minimum when α gets maximum. In Figure 1(a), with the chip locates to the left side with angle α_0, and the accelerator in anti-clock direction, the critical condition for actuating the chip is that the total angular moment of both force is positive, $\boldsymbol{P}>0$. So the minimum accelerator required to actuate the chip is expressed as

$$\frac{d\omega}{dt} > \omega^2 \frac{\int_S \rho_s r' r \sin\beta . ds}{\int_S \rho_s r' r \cos\beta . ds} \quad (5)$$

The angular moment is a nonlinear function of the position. Therefore, strictly it is not possible to define a uniform effective center of mass and simplify the equation (5), for a chip with distributed mass. However, for simplicity in analysis, we could assume the mass of chip is condensed on to an effective center, and then it will be easy to calculate P_E, P_ω, and the required accelerator. In practice, if the maximum accelerator that the motor could provide is not large enough, two weights could be introduced to cancel the effect of centrifugal force. These two weights are located symmetrically on the top of the chip with maximum angle of swinging, as shown in Figure 2. Then the extension of the centrifugal force of weight1 will go through the axis O/, meaning no contribution to the total angular moment. Then the angular moment of weight2 will cancel part of P_ω, and make the switching become easier, with lower accelerator required. For multiplex issue, at least 4 'pendulum' could be allocated on one disc, with each one occupies one quarter of the disc. The stop nuts at the boundary could be shared by adjacent chip.

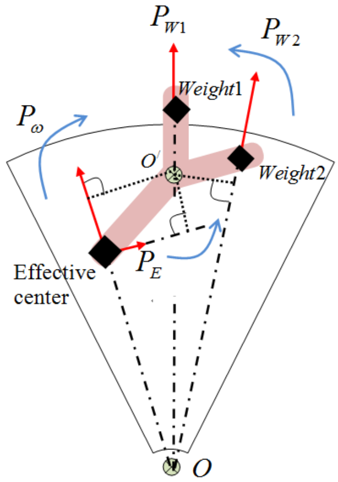

Figure 2 Simplified angular moment diagram with two weights located at the top of chip