Oscillating leaflet across a channel

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The computational domain is a $L \times H$ channel with a $h \times w$ leaflet located across it as shown in Figure 1. A periodic flow condition is prescribed on the inlet and outlet boundaries, given by $u_x = 15.0y\,(2-y)\,sin\,(2\pi t)$. Gravity is not considered in the first test case (i.e. $\mathbf{g} = 0$), and other fluid and solid properties are presented in Table 1. Taking the average velocity $\bar{U} = \int_0^H u_x dy = 10$ and the channel height H as the characteristic velocity and length respectively, the Reynolds number is: $Re = \frac{\rho^f \bar{U} H}{\nu^f} = 100$.

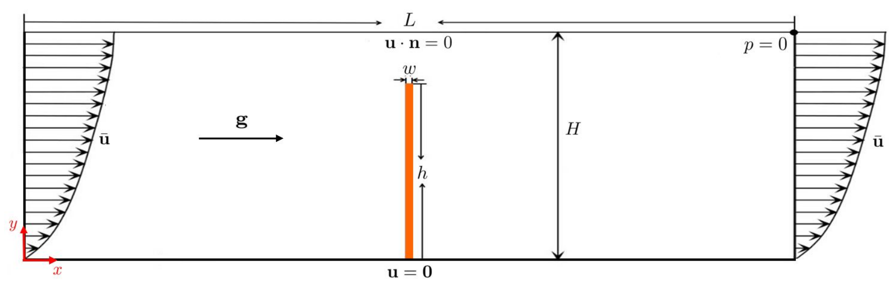
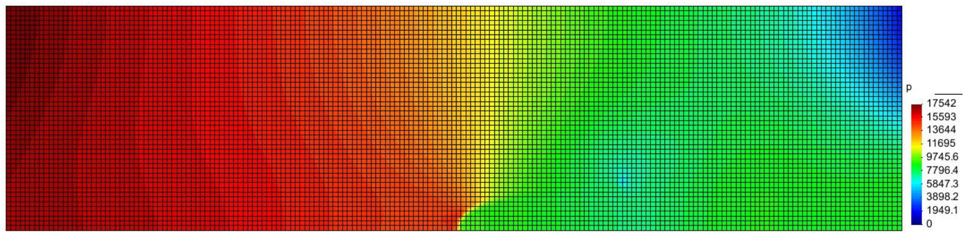


Figure 1: Computational domain and boundary conditions.

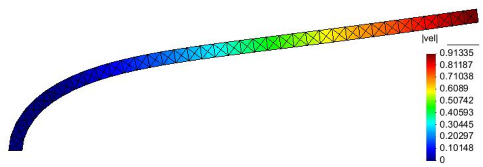
Fluid	Leaflet
$L = 4.0\ m$	$w = 0.0212\ m$
$H = 1.0\ m$	$h = 0.8\ m$
$\rho^f = 100\ kg/\,m^3$	$\rho^s = 100\ kg/\,m^3$
$\nu^f = 10\ N \cdot s/\,m^2$	$\mu^s = 10^7\ N/\,m^2$

Table 1: Material properties for the problem.

A uniform mesh is used in this simulation and the result is compared with an ALE fitted mesh method. In order to show the meshes, the pressure on the fluid mesh and velocity on the deformed solid mesh are presented in Figure 2. The same mesh size is adopted for the ALE method as shown in Figure 3, from which it can be seen that the ALE mesh cannot be trusted after around $t = 0.12$ if we check the mesh closely at the tip and bottom of the leaflet. However we can carry on the simulation using the proposed two-mesh method, and the accuracy can be compared with the ALE method before $t = 0.12$ which is very good (see Figure 4 to 6).

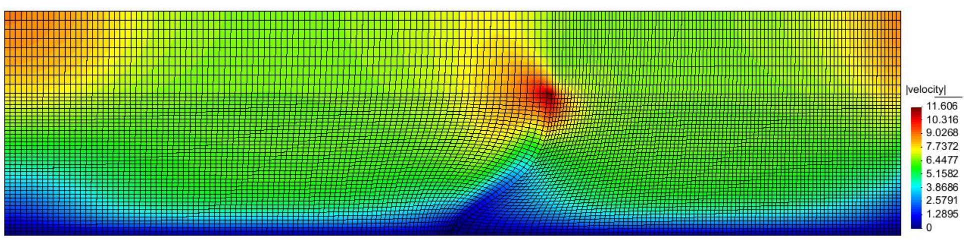


(a) P_2/P_1 elements for velocity and pressure, the size of one element is the same as the width of the solid leaflet (0.0212).

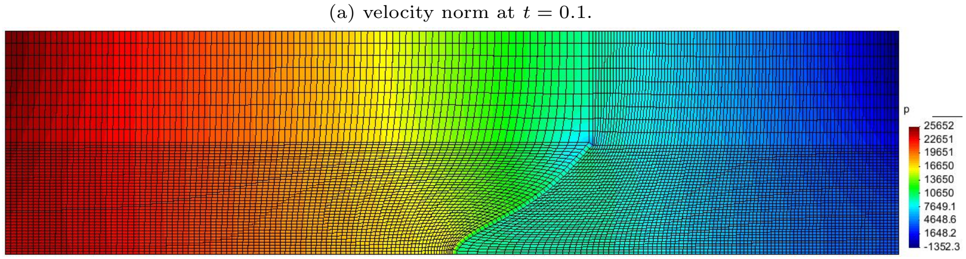


(b) Bilinear solid mesh.

Figure 2: Distribution of pressure on the fluid mesh and velocity norm on the solid mesh at $t = 1.0$.

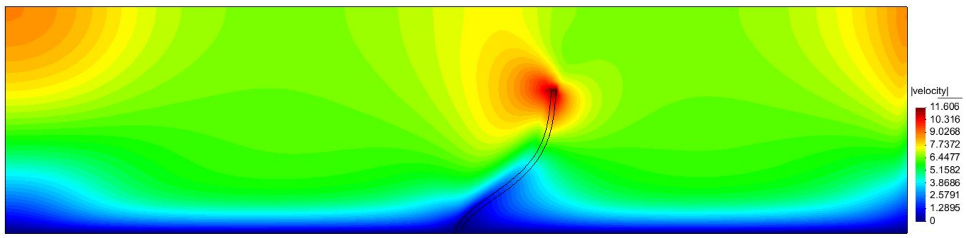


(a) velocity norm at $t = 0.1$.

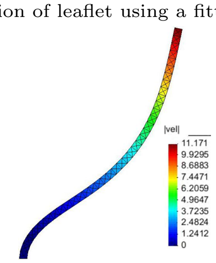


(b) Pressure at $t = 0.12$,

Figure 3: Distribution of pressure and velocity norm using an ALE mesh (same mesh as in Figure 2 (a)).

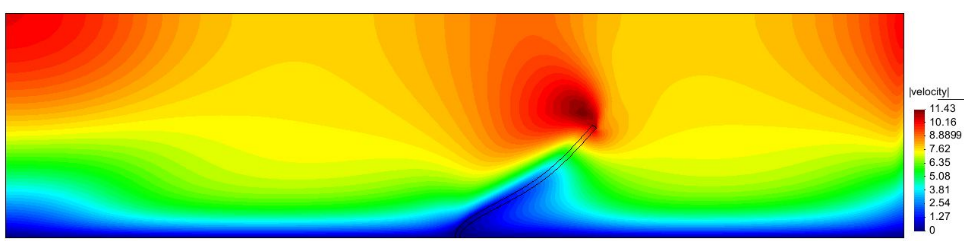


(a) Deformation of leaflet using a fitted ALE mesh.

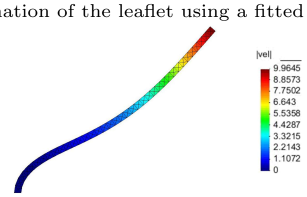


(b) Defomation of the solid leaflet using the proposed two-mesh method.

Figure 4: Comparison of the leaflet deformation at $t = 0.1$.

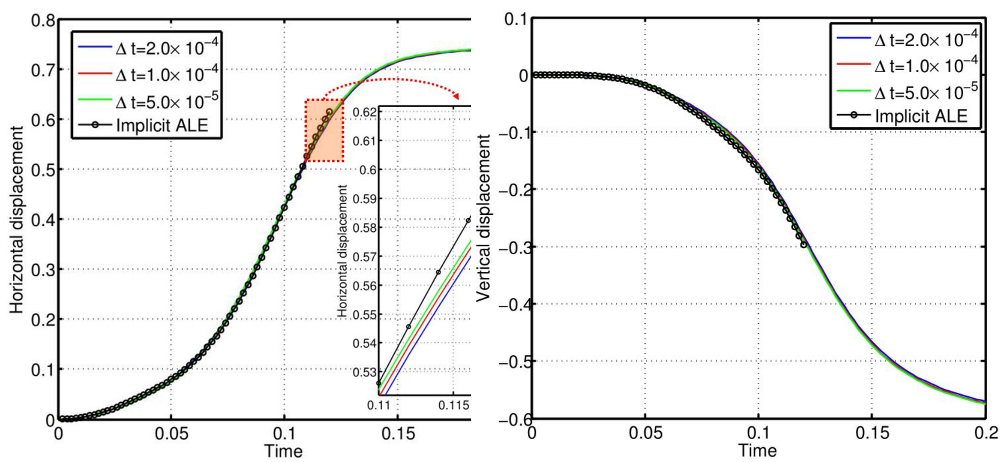


(a) Deformation of the leaflet using a fitted ALE mesh.



(b) Defomation of the solid leaflet using the proposed two-mesh method.

Figure 5: Comparison of the leaflet deformation at $t = 0.12$.



(a) Horizontal displacement against time.

(b) Vertical displacement against time.

Figure 6: Comparison of displacement at the leaflet tip (top-left corner). The implicit ALE method uses a stable/converged time step of $\Delta t = 1.0 \times 10^{-4}$.