Energy Harvesting in a Fluid Flow Using Piezoelectric Materials

M. Curatolo[1], M. La Rosa[1] , P. Prestininzi[1]
1. Engineering Department, Roma Tre University, Rome, Italy

INTRODUCTION: Energy harvesting using piezoelectric materials has been deeply investigated over the last decade [1]. Here, we focus on harvesting energy from a flowing fluid which is a recent application of such materials [2]. The 2D model consists of a fluid channel and a solid bilayer structure (see Fig. 1).

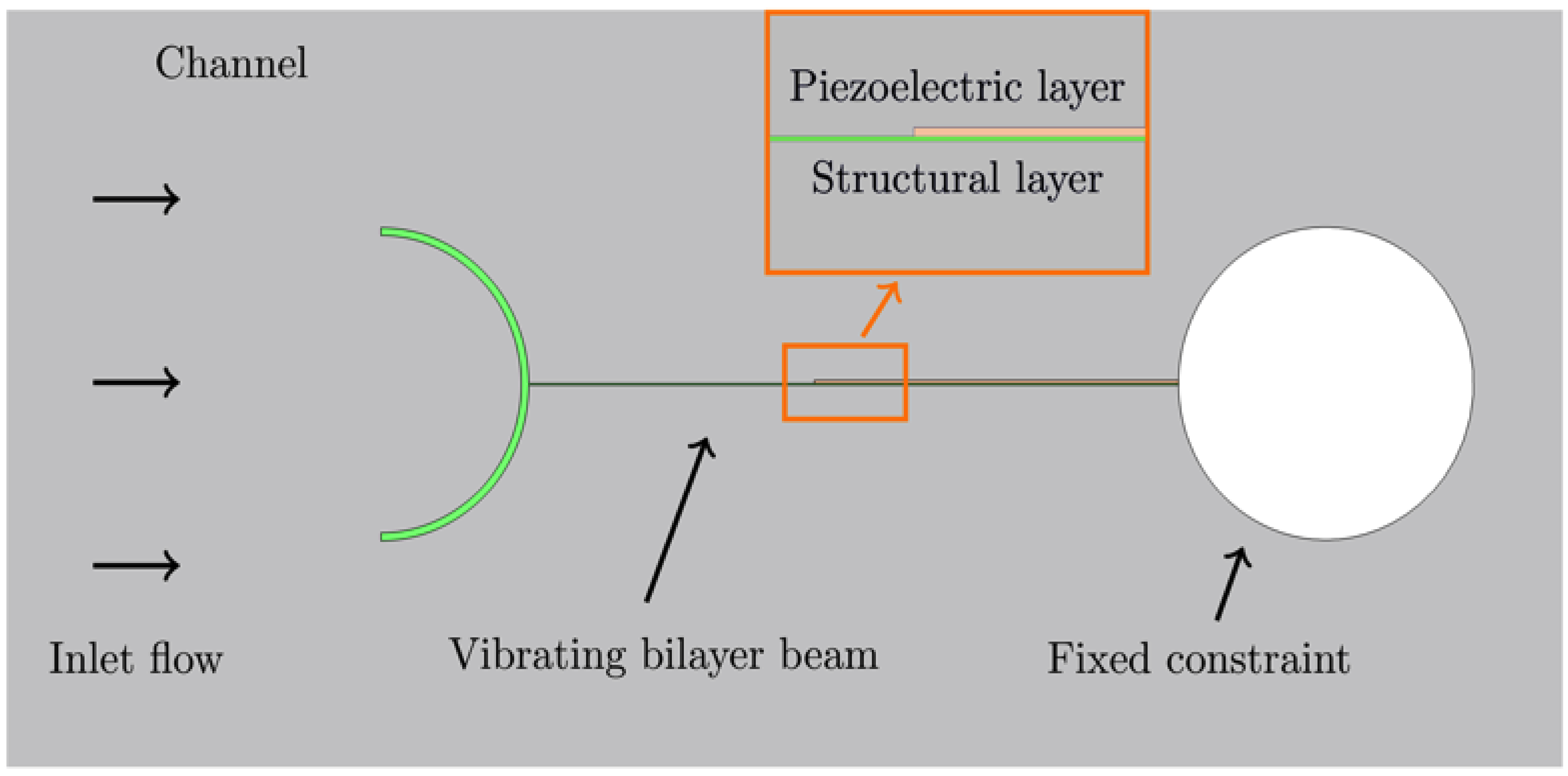

Figure 1. Geometry of the model.

PIEZOELECTRIC MATERIALS: Piezoelectric solids develop an electric potential when compressed or stretched. The optimal external resistance depends on geometry and characteristics of force application (for example its frequency, see cartoon in Fig. 2).

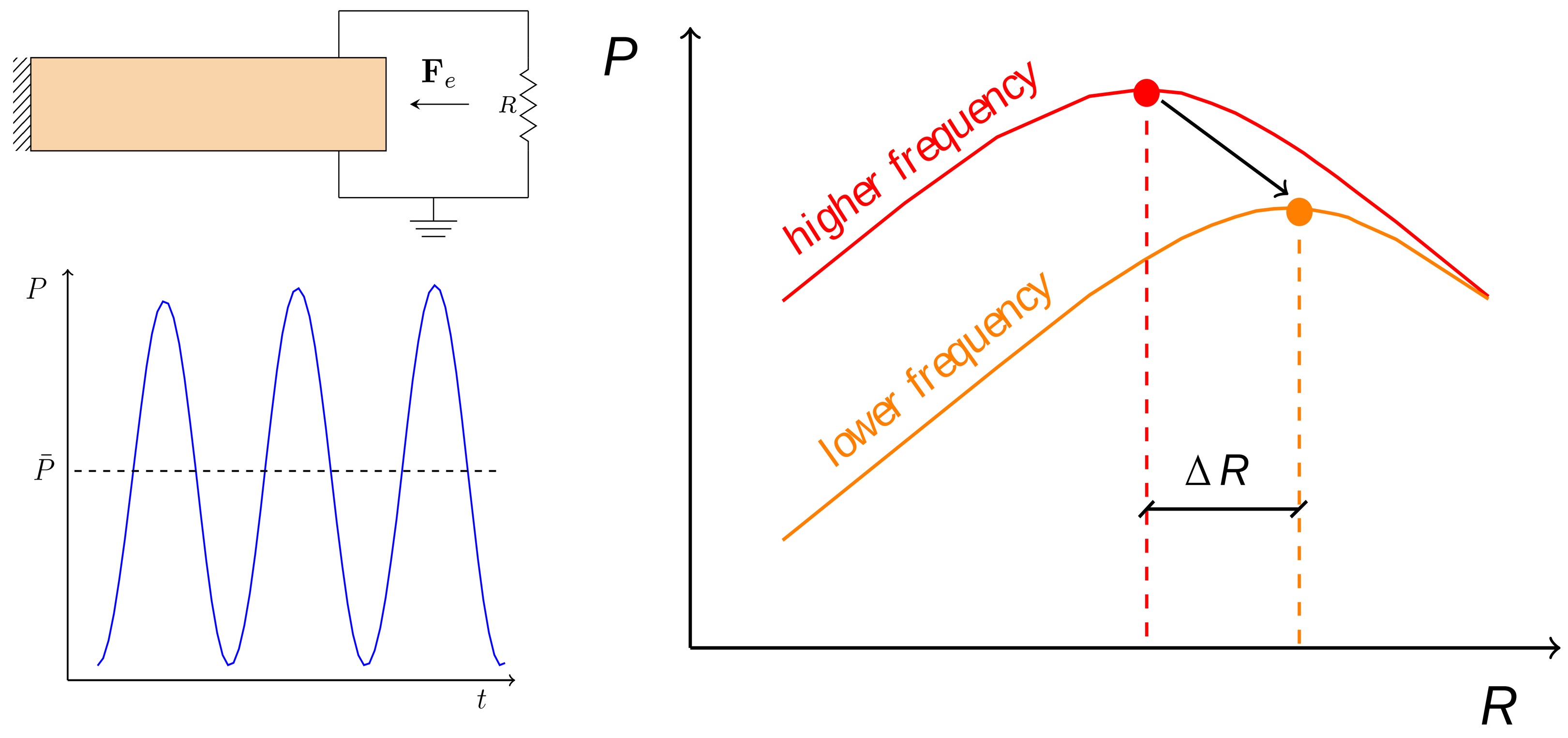

Figure 2. A piezoelectric solid undergoing periodic 1D deformation induced by external load is connected to an external electrical load. The value of such external electrical load maximizing harvested power power is greater at lower force frequencies.

COMPUTATIONAL METHODS: Fluid and solid mechanics are coupled through the fluid-solid interaction package of COMSOL®. Balance equations of the problem are:

$$\rho_f\,\dot{\mathbf{v}}_f + \rho_f\,(\nabla \mathbf{v}_f)\,(\mathbf{v}_f - \dot{\mathbf{u}}_m) = \operatorname{div}\boldsymbol{\Gamma} + \mathbf{f} \qquad \operatorname{div}\mathbf{v}_f = 0$$

Momentum and mass conservation

$$\rho\,\ddot{\mathbf{u}} = \operatorname{div}\mathbf{S}$$

Solid balance of forces

$$\operatorname{div}\mathbf{D} = \rho_v$$

Gauss law

$$\operatorname{div}(\mathbb{A}\nabla \mathbf{u}_m) = 0$$

Moving mesh

This system of equations is solved using appropriate initial and boundary conditions, the arbirtrary lagrangian-eulerian (ALE) formulation and the re-meshing feature which describes accurately large displacements of the deformable solid and its interaction with the fluid [3, 4]. Reynolds number of simulations is $\mathrm{Re} \backsim 10^5$.

RESULTS: Results of the model include: deformation of the solid, fluid pressure, fluid velocity field and harvested electrical power.

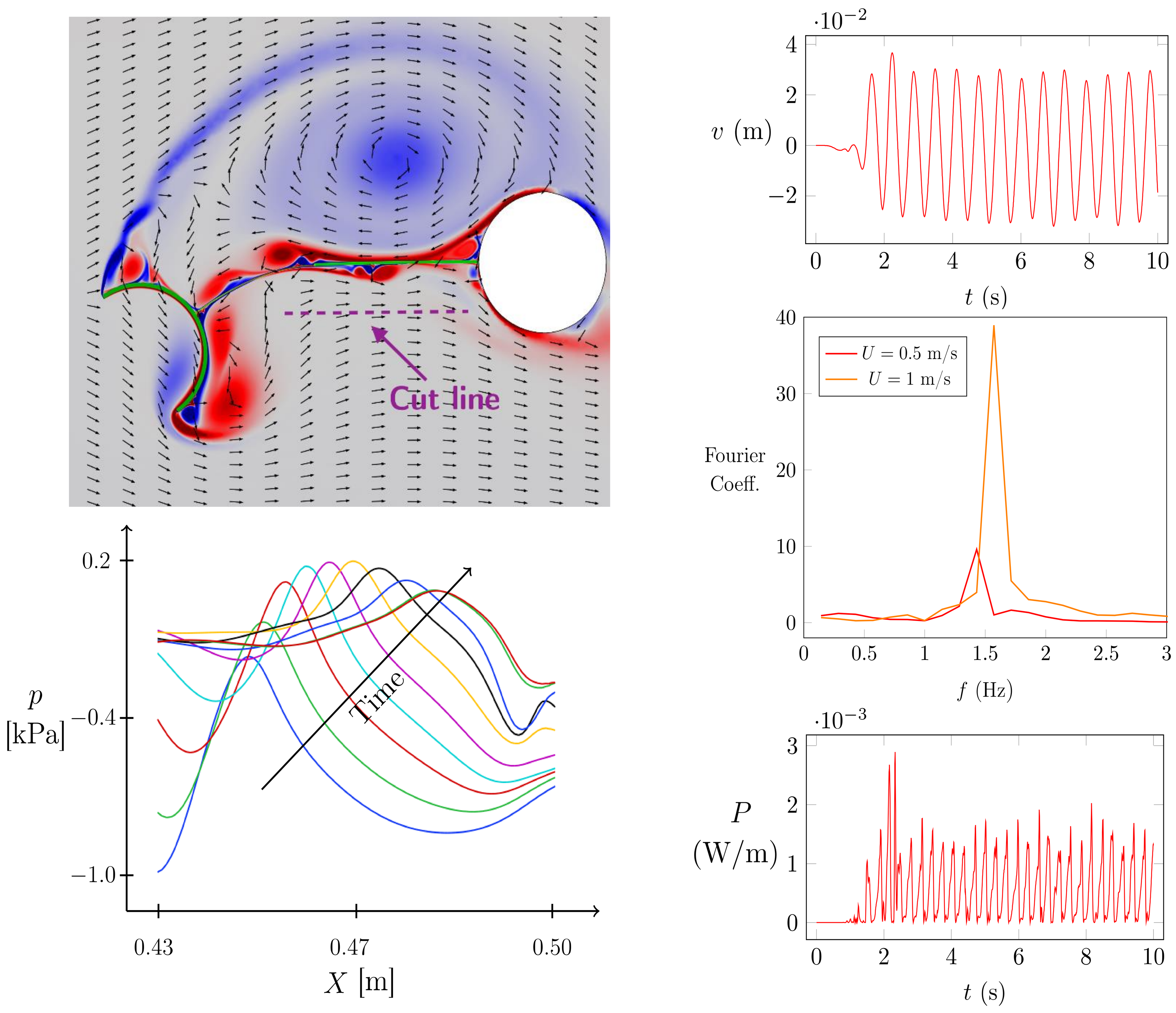

Figure 3. Left: Zoom of vorticity field and cut line where the pressure is evaluated at different instants. Right: Vertical displacement at tip, its frequency spectrum at different inlet velocities and electric power harvested.

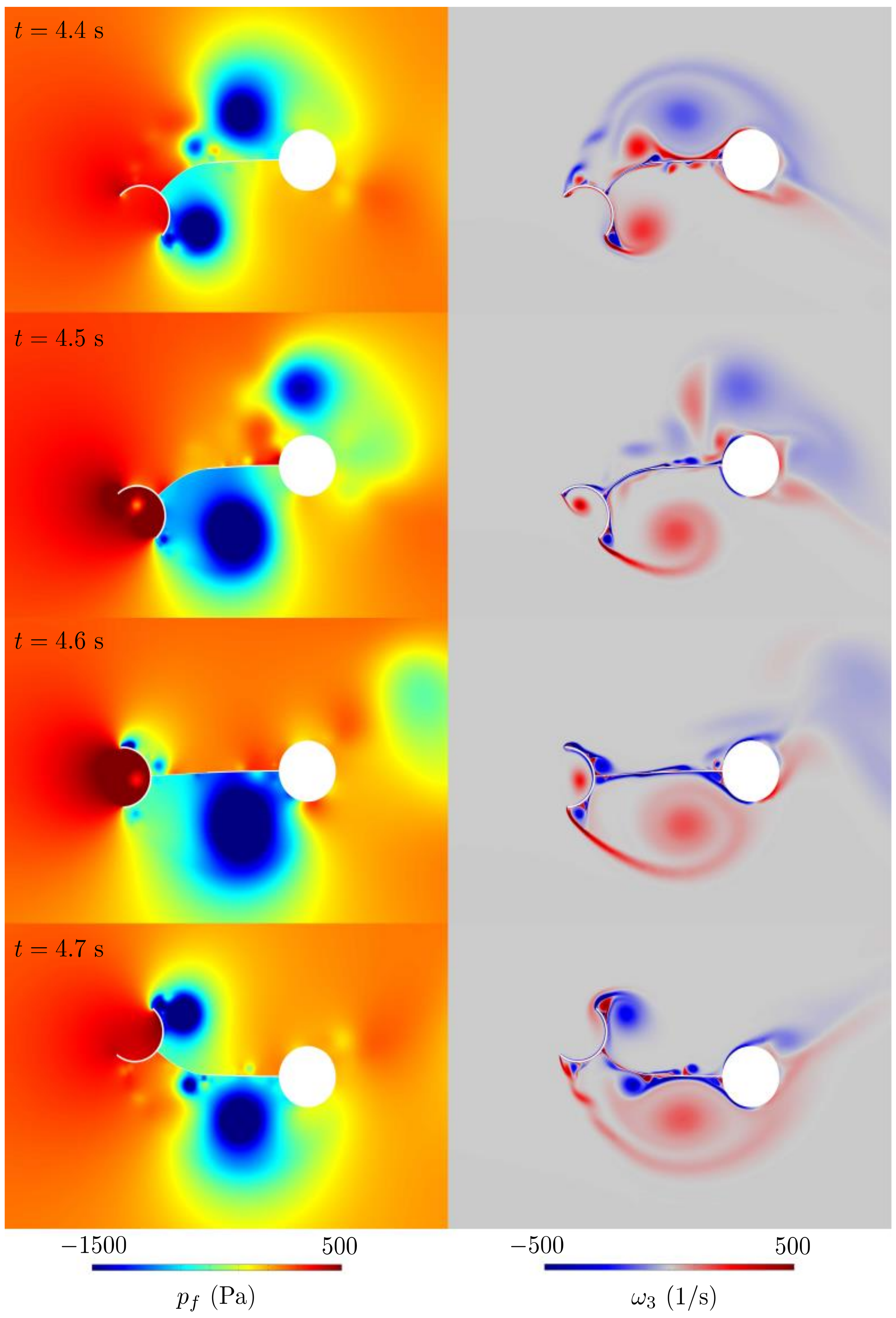

Figure 4. Pressure and vorticity fields at different instants.

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