SUPPLEMENTARY MATERIAL

APPENDIX A: Equivalence between fluid forces and parameters in the model

The physical model considered in the manuscript is a generic model representing an axially-moving string subjected to a distributed follower force. In this model, the direction of the transverse velocity v_{tr} is considered to be vertical and it is the total derivative of the transverse displacement '$w(x,t)$'.

This generic model can be applied to the case of the string moving in fluid with suitable equivalence. To show the equivalence between such a case and the formulation in the model, first consider a cylinder placed exactly normal to the flow of fluid as shown in Fig. R1(a). In this case, the cylinder experiences a resistive force, say $f_{N_{\pi/2}}$, as shown. This force actually contains two components, one due to form drag and the other due to skin friction. In the limiting case when the diameter of the cylinder is very small, the friction drag coefficient dominates over the form drag coefficient, as shown for instance in S[1]. Note that only this component in the normal force that arises due to form drag is neglected in the physical model presented in the manuscript, and not the entire normal force.

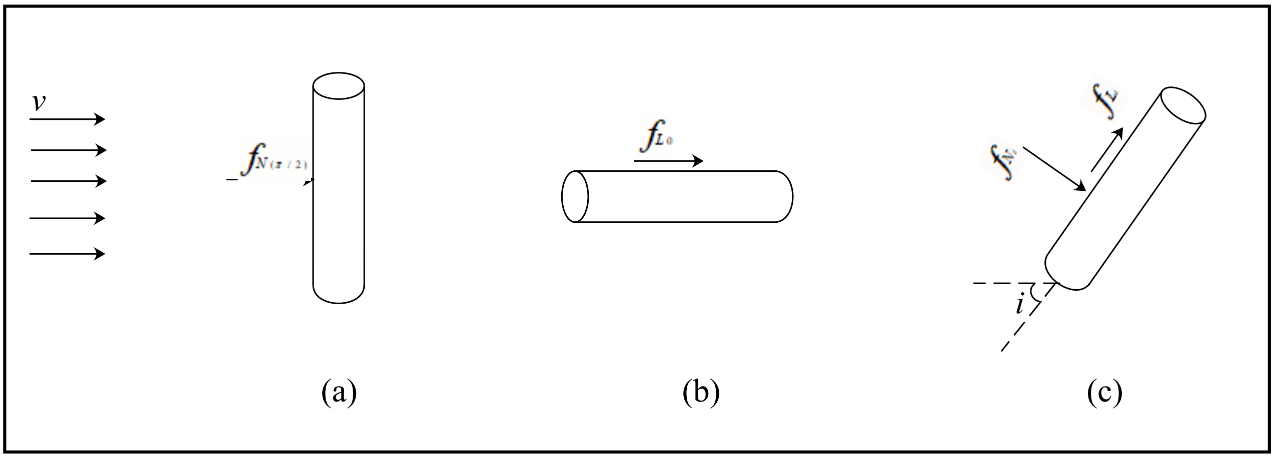

Figure R1: Cylinder placed in a fluid flow.

Following the results of reference S[1], when a cylinder is placed parallel to the flow of fluid as shown in Fig. R1(b), it experiences a force f_{L0} which is largely due to skin friction. Now consider a cylinder placed inclined at an angle 'i' to the flow of fluid. This is equivalent to the case of the string vibrating in the transverse direction along with its axial motion in fluid. In this case, the relative velocity between the fluid and the cylinder is $\sqrt{v_{tr}^2 + v^2}$. When the fluid flow speed is much higher than the transverse velocity of the cylinder, one can linearize as S[2], $sin(i) = \frac{v_{tr}}{\sqrt{v_{tr}^2+v^2}} \approx \frac{v_{tr}}{v}$ and $cos(i) = \frac{v}{\sqrt{v_{tr}^2+v^2}} \approx 1$. This inclined cylinder experiences a force which can be divided into two components as shown in Fig. R1(c):

$$f_{N_i} = \frac{1}{2}\rho_f D v^2 (C_D sin^2(i) + C_f sin(i))$$
$$f_{L_i} = \frac{1}{2}\rho_f D v^2 C_f cos(i)$$

where ρ_f, D, C_D and C_f are density of fluid, diameter of the cylinder, form and friction drag coefficients. As already mentioned, in the case of the string, C_D is negligible compared to C_f. Therefore, for a particular flow velocity, the component which is normal to the axis of the cylinder can be written as '$cv_{tr}(= \frac{1}{2}\rho_f D v C_f v_{tr})$'. Thus, the damping coefficient in the presented model can be equivalently related to the normal component of the resistive force experienced by the string. Similarly, the component which is parallel to the axis of the cylinder can be equivalently considered to be a distributed follower force, '$p(= \frac{1}{2}\rho_f D v^2 C_f)$' as is done in the physical model presented in the manuscript.

References

S1. Taylor G. I. Analysis of the swimming of long and narrow animals. *Proceedings of the Royal Society A*, 211:255–239, 1952.

S2. M. P. Gosselin, F. Paidoussis and A. K. Misra. Stability of a deploying/extruding beam in dense fluid. *Journal of Sound and Vibration*, 299:123–142, 2007.