EXTENDED ABSTRACT:

STABILITY OF A SPRING-MOUNTED CANTILEVERED FLEXIBLE PLATE IN A UNIFORM FLOW

R.M. Howell† & A.D. Lucey†

† *Fluid Dynamics Research Group, Curtin University of Technology, GPO Box U1987, Perth, WA 6845, Australia.*
E-mail: A.Lucey@Curtin.edu.au

1 INTRODUCTION

In the recent study of simply supported or cantilevered plates in uniform axial flow first studied by Kornecki *et al.* (1976), a popular idea has been that of using the flutter instabilities observed in the system to generate useful electrical energy harvested by various means; see for examples Allen & Smits (2001) and Tang *et al.* (2009). This has led us to investigate a new fundamental system, where the cantilever is not fixed but can move freely in the vertical axis being attached at its leading edge to a rigid base by mounting it upon a linear spring; this new system is depicted in Figure 1 that also shows the inclusion of a rigid inlet surface upstream of and fixed to the cantilever. A future rôle of this system could clearly be to add in the linear damper to allow the study of the energy-generation possibilities of the new system. In this paper we combine the findings of our preliminary studies in 2012 - see Howell & Lucey (2012 a,b) - and present our definitive key results. We map out the dynamics of the parameter space in the absence of damping that we find depends upon the mass ratio and the critical velocity $\bar{L}$ and $\bar{U}_c$ and additionally the natural frequency of the support $\bar{\omega}_s$ of the spring-mass system and the length and mass of the rigid-inlet $\bar{L}_s$ and $\bar{M}_s$. We then introduce damping at the leading edge mass-spring support system and examine the power extraction characteristics.

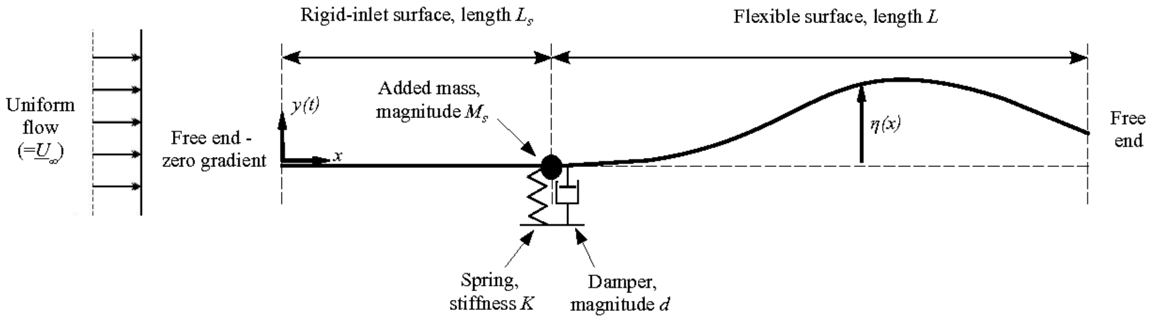

Figure 1: The fluid-structure system under consideration.

2 SYSTEM MODELLING

The methods of Howell *et al.* (2009, 2011) that mixed numerical simulation with eigenvalue analysis and incorporated the effects of added point mass are further extended to incorporate the new system mechanics. An ideal two-dimensional flow is assumed wherein the rotationality of the boundary-layers is modelled by vortex elements on the solid-fluid interface and the imposition of the Kutta condition at the plate's trailing edge. The Euler-Bernoulli beam model is used for the structural dynamics. Simply supported free beams where the support can move vertically are analysed in studies of insect flight, for example see Manela (2012), and constrain that the leading edge must follow (1) the heaving motion and (2) the pitching motion of the actuating force. In our study these constraints are applied through the application of (1) a non-zero normal velocity at all panel control points equal to the velocity of the first mass point and (2) zero vertical gradient between the cantilever and the first mass point along the flexible beam.

3 ILLUSTRATIVE RESULTS

In Figures 2 (a) and (b) we reproduce the results of Howell *et al.* (2009) of the variation of system eigenvalues with flow speed and critical mode shape at instability onset for a fixed cantilever-free beam in axial flow with a rigid inlet surface equal in length to the length of the flexible beam upstream of the beam. The plate becomes unstable through a modal-coalescence flutter (mode 3 in Figure 2 (a) - thick green line). Figures 2 (c) and (d) show the effect on these results of the now oscillating cantilever: the critical mode shape is seen to lose its higher-order mode content and the reason for this is clearly seen in

Figure 2 (c) as the previously stable mode 2 has been ‘tripped’ by the introduced spring and causes the system to destabilise at a far lower critical velocity through single-mode flutter (mode 2 in Figure 2 (c) - thick red line).

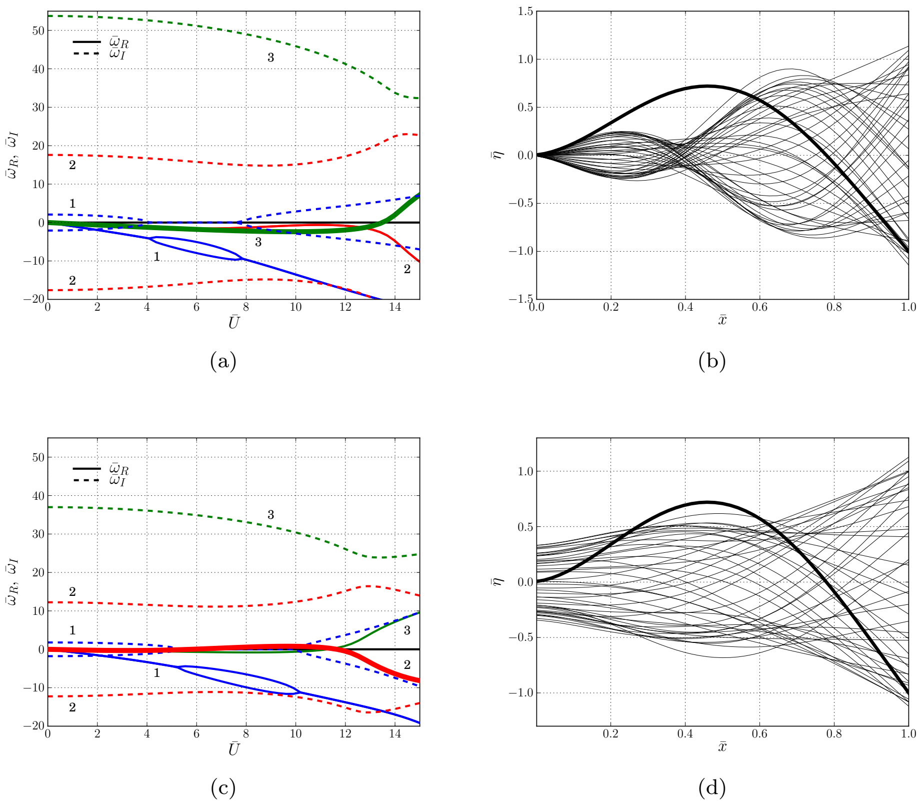

Figure 2: Argand diagrams ((a) and (c)) and critical mode shapes ((b) and (d)) for a fixed ((a) and (b)) and a mobile ((c) and (d)) cantilever. The thick line in (b) and (d) depicts the initial deflection of the beam. For the fixed cantilever, $\bar{U}_c = 13.48$. For the mobile cantilever, $\bar{U}_c = 5.77$ with $\bar{\omega}_n = 10$ and $\bar{L}_s = 1$. In both cases $\bar{L} = 1$.

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5 KEYWORDS

Fluid-structure interaction, flutter, energy extraction, spring-mounted cantilever