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# A NUMERICAL INVESTIGATION OF TBA.....!!!1

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# CHAPTER 1

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## GOVERNING PARAMETERS OF FLUID-ELASTIC GALLOPING

### 1.1 Introduction

This chapter contains the formulation of non dimensional governing parameters namely, the combined mass-stiffness  $\Pi_1$  and the combined mass-damping  $\Pi_2$  and the results and discussion demonstrating the influence of them. These parameters are formulated by obtaining the relevant time-scales of the system followed by non-dimesnionlising the governing QSS oscillator equation.

A comparison of Quasi-steady state data presented using the classical VIV parameters and the newly formulated  $\Pi_1$  and  $\Pi_2$  is presented and it is concluded that  $\Pi_2$  provides a better collapse for velocity amplitude and mean power compared the classical reduced velocity ( $U^*$ ) particularly because unlike  $U^*$ ,  $\Pi_2$  does not include a frequency component in it. This is followed by the presentation of QSS data and discussion on the influence of  $\Pi_1$  and  $\Pi_2$  on power, which concludes that the power transfer is a primary function of  $\Pi_2$  and a weak function of  $\Pi_1$ .

Following this, a comparison of the QSS data with Direct Numerical Simulations (DNS) is presented. This reveals that the power transfer of the DNS data is strongly influenced by both  $\Pi_1$  and  $\Pi_2$ . Further analysis reveals that there is a good agreement between QSS and DNS for velocity and power at substantially high  $\Pi_1$ . As  $\Pi_1$  decreases, the deviation

(between QSS simulations and DNS) increases. Power spectral analysis of the DNS data shows a significant response at the vortex shedding at low  $\Pi_1$ . The relative strength was found out to be an inverse function of  $\Pi_1$ , which provides a clear explanation for the deviation between QSS simulations and DNS data at low  $\Pi_1$ . This is primarily due to the influence of vortex shedding where this effect is not accounted in the QSS model.

## 1.2 Formulation of the non-dimensionalised parameters $\Pi_1$ and $\Pi_2$

The natural time scales of the system could be obtained by linearising the quasi-steady equation of motion. (Eq: *\*\*KJ: equation of motion \*\**) and finding the eigenvalues. The non-linear terms of the forcing function are truncated and the equation of motion could be expressed as,

$$m\ddot{y} + c\dot{y} + ky = \frac{1}{2}\rho U^2 \mathcal{A}a_1 \left( \frac{\dot{y}}{U} \right), \quad (1.1)$$

After combining the  $\dot{y}$  terms and solving for eigenvalues the following solutions for the eigenvalues could be obtained.

$$\lambda_{1,2} = -\frac{1}{2} \frac{c - \frac{1}{2}\rho U \mathcal{A}a_1}{m} \pm \frac{1}{2} \sqrt{\left[ \frac{c - \frac{1}{2}\rho U \mathcal{A}a_1}{(m)} \right]^2 - 4 \frac{k}{m}}. \quad (1.2)$$

Galloping essentially occurs at low frequencies therefore it can be assumed that the spring is relevantly weak and therefore,  $k \rightarrow 0$ . Hence a single non-zero eigenvalue remains which is,

$$\lambda = -\frac{c - \frac{1}{2}\rho U \mathcal{A}a_1}{m}. \quad (1.3)$$

Further, if it is assumed that the mechanical damping is weaker than the fluid dynamic forces on the body the non zero eigenvalue could be further simplified to,

$$\lambda = \frac{\frac{1}{2}\rho U \mathcal{A}a_1}{m}. \quad (1.4)$$

In this representation  $\lambda$





