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EMPIRICAL FLUID-ELASTIC MODELS AND CHAOTIC GALLOPING: A CASE STUDY

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To describe the behavior of bluff body fluid-elastic motions, analysts must in practice resort to empirical models based on a limited number of measured fluid-elastic behavior characteristics. To our knowledge the question of whether such models can predict reliably the actual occurrence of chaos has not yet been addressed. With a view to answering this question in a specific case, we present an exploratory experimental and numerical study of two paradigmatic fluid-elastic systems: (1) a single galloping square prism; and (2) a pair of elastically coupled galloping prisms which can exhibit apparently chaotic behavior of interest from a structural engineering viewpoint. We review various conventional empirical models and their capabilities, and develop a model that incorporates information on the dependence on angle of attack of the vortex-induced lift coefficient and the Strouhal number for the stationary prism. For appropriate values of the adjustable parameters and initial conditions, this model appears to be able to describe observed behavior at least qualitatively. However, the predictive capabilities of the model are poor, especially for apparently chaotic behavior. A possible approach to improving the reliability of the numerical detection of such behavior is suggested.

1. INTRODUCTION

Experience shows that as novel, increasingly daring types of structures emerge, they may be affected by unsuspected forms of undesirable behavior. Cast iron column buckling before Euler and suspension bridge flutter 50 years ago are cases in point. As compliant structures are built in increasingly deeper waters and exhibit increasingly strong non-linearities, there is concern that they may be affected by undesirable fluid-elastic behavior, including chaotic behavior [1–3]. Thus recent progress in dynamical systems theory has stimulated interest in the chaotic behavior of compliant offshore structures, or elements thereof, and of other fluid-elastic systems [3–8].

In offshore structures the oscillating bodies are bluff, and if flow separation effects are significant the fluid-elastic loads can seldom in practice be obtained by solving the Navier–Stokes equations. For this reason the analyst is forced to resort to empirical models. Chaotic dynamics studies of bluff body fluid-elastic systems quoted earlier do not include comparisons between results of empirical modeling and experiment. Thus, the question of whether empirical fluid-elastic models can predict reliably the actual occurrence of motions that are or appear to be chaotic remains open.

The purpose of this paper is to address this question in a specific case. To this end we conducted an exploratory experimental and numerical study of the two simple bluff body fluid-elastic systems shown in Figure 1, referred to for brevity as the single and the double oscillator. The systems were chosen on account of their interesting dynamic behavior, of their relative simplicity compared to the well-known case of the circular cylinder (from

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