#52

The American Society of
Mechanical Engineers
Offshore Mechanics & Arctic Engineering (OMAE) Division

Offshore Mechanics and Arctic Engineering
(OMAE) Division, Calgary Chapter
P.O. Box 39, Life Plaza Building
734 - 7th Avenue S.W., Calgary, AB. T2P 3T8 Canada

OMAE 1992 – CALGARY, CANADA

11th International Conference on Offshore Mechanics and Arctic Engineering
June 7th – 11th, 1992

NOISE MODELING AND RELIABILITY OF BEHAVIOR PREDICTION FOR MULTI-STABLE HYDROELASTIC SYSTEMS

Emil Simiu
Building and Fire Research Laboratory
National Institute of Standards and Technology
Gaithersburg, MD 20899, USA

Michael Frey
Computing and Applied Mathematics Laboratory
National Institute of Standards and Technology
Gaithersburg, MD 20899, USA

ABSTRACT

This paper reviews results of experiments conducted on a simple multi-stable hydroelastic (galloping) oscillator. These results show that noise may cause a multi-stable hydroelastic system to exhibit chaotic behavior, and that in some instances such behavior cannot be predicted reliably unless noise effects are carefully accounted for. We then present results of a theoretical investigation of a simple, paradigmatic multi-stable system, the Duffing-Holmes oscillator. The results of this investigation show that for the system being considered noise promotes the occurrence of chaotic behavior associated with Smale horseshoes. This theoretical investigation is the first phase of an effort to develop analytical tools for predicting reliably the potential for chaotic behavior of actual hydroelastic systems such as deep-water compliant platforms.

INTRODUCTION

Thompson et al. (1984) noted that experiments and numerical studies conducted on compliant offshore structures can reveal the possible occurrence of unexpected types of dynamic behavior, including deterministic chaos. Overlooking certain types of behavior can constitute a gross design error with possibly disastrous consequences. Such a design error led in 1836 to the collapse by flutter of the Brighton Chain Pier bridge. Neither this precedent nor the development of flutter theory by Theodorsen (1935) were understood by the bridge design community, and an identical design error led to the well-known collapse in 1940 of the Tacoma-Narrows bridge.

In the studies by Thompson et al. (1984) the chaotic behavior of the system of interest occurred in a hydroelastic system excited by periodic loads. More recently, experiments and numerical studies performed on a simple, paradigmatic hydroelastic system showed that irregular behavior involving catastrophic jumps between distinct regions of phase space could also be induced by the noise excitation of a multi-stable system (Simiu and Cook, 1991, 1992). It is this finding that motivated the present work.

Mathematically, there is an apparent distinction between chaotic (i.e., irregular) "basin-hopping" behavior with jumps induced by stochastic excitation or noise (Arecchi et al., 1983), and behavior exhibiting jumps associated with deterministic chaos (i.e., behavior that entails the formation of Smale horseshoes and, therefore, sensitivity to initial conditions, at least one positive Lyapounov exponent, basins of attraction with fractal dimension, and the existence of a strange attractor with fractal dimension (Guckenheimer and Holmes, 1983)). As suggested by experimental and numerical results (Simiu and Cook, 1992), those two types of behavior can in fact be indistinguishable phenomenologically.

In this paper we present a theoretical investigation which shows that, for a certain class of systems and for certain regions of parameter space, what appears to be basin hopping caused by any given realization of a noisy process is in fact noise-induced chaotic behavior associated with the formation of Smale horseshoes. This eliminates the mathematical distinction noted earlier. Basic theory yields in this case necessary conditions for the occurrence of such chaotic behavior, as well as a useful measure of its strength as reflected, for example, in the frequency of the jumps.

As compliant offshore structures are being envisaged for deeper waters and can therefore be anticipated to exhibit more complex nonlinear behavior, noise effects may be expected to become increasingly significant. Indeed, numerical simulations as well as our theoretical investigation show clearly that the effects of noise can be crucial in determining the behavior of nonlinear multi-stable systems. Those effects should therefore be accounted for if a reliable prediction of dynamic behavior is sought. Recognizing this is an important first step toward the realistic modeling of bi- or multi-stable compliant hydroelastic system behavior. Numerical simulations and tools based on theory can provide valuable insights into the behavior of such systems, just as Theodorsen's (1932) fundamental work on airfoil flutter could have provided useful early insights into