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Comparative Evaluation of Numerical Schemes for 2D Mooring Dynamics

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ABSTRACT

The paper deals with the presentation and the comparative evaluation of 2 different numerical schemes suitable for 2D mooring dynamic analysis. A finite differences scheme and a spectral method are treated. Several solution methodologies for studying the dynamic behavior of mooring lines have been reported in the past. However, a solution feature which should be further investigated, and nowadays becomes of special importance in conjunction with the development of integrated numerical tools for moored body-wave interaction problems, is concerned with the efficiency and the reliability of the various schemes. Towards contributing in this direction, the 2 numerical solutions are first outlined and then their advantages and disadvantages examined on the basis of extensive numerical results for a synthetic mooring line.

INTRODUCTION

The dynamics of mooring lines have attracted the attention of many researchers during the last two decades because of the variety of the applications in which they can be used (Goodman and Breslin, 1976; Triantafyllou et al., 1985; Fylling et al., 1987; Mavrakos et al., 1989; Papazoglou et al., 1990; Howell, 1991; Mavrakos and Chatjigeorgiou, 1997; Sun and Leonard, 1998; Shukai, 1999). During that period, special attention was paid to the development of accurate dynamic analysis methods suited to the particular application being considered (deep-water applications, low-tension cables, towed-cable systems, bottom-line interaction models, etc.). The necessity of accuracy led to the development of numerical methods that allowed the inclusion of several nonlinear terms in the dynamic system.

For the solution of the developed governing equations, algorithms both in the frequency and in time domain were developed. The frequency domain solution methods, which usually account for the nonlinear drag force on the cable through its equivalent linearization, represent a first approximation to the mooring line's dynamic behavior. As far as the time domain solution methods are concerned, explicit and implicit formulations have been developed, the explicit ones representing the majority among them. In addition, several approximate formulations have been presented in the literature (Mavrakos et al., 1989; Papazoglou et al., 1990), suitable for wire cables under high pretension, that neglected some nonlinear terms involved in the governing equations. The latter, without losing on predominant contributions, led to an essential improvement of the efficiency of the developed numerical schemes. It should be mentioned, however, that the underlying assumptions of such approximate formulations placed the accuracy of obtained numerical predictions under dispute for some cases, especially when the excitation frequency was approaching the first natural frequency of the dynamic system (Chatjigeorgiou and Mavrakos, 1997).

It is obvious, therefore, that as long as the target is the accuracy of the numerical predictions, the governing equations must be solved by making as few simplifying assumptions as possible, which in turn leads to solutions in the time domain. In that context, the efficiency of the numerical solution schemes and the associated computer codes are of paramount importance. It is common knowledge that the most efficient and reliable numerical algorithms are the implicit ones.

The scope of the present study is to contribute towards that direction by assessing the efficiency of 2 different time domain solution schemes. The governing equations are solved in 2D space. The time interaction is carried out implicitly. One solution scheme is based on a so-called collocation method, while the other relies on a finite differences formulation. An outline of each method and of the corresponding solution procedure is presented below; the two numerical algorithms are then comparatively evaluated. Numerical results for a synthetic mooring line that possesses a nonlinear stress-strain relation are given.

DYNAMIC EQUILIBRIUM IN 2-D SPACE

The cable is modeled as a slender rod without bending stiffness. Let s denote the unstretched Lagragian coordinate measured from the lower cable end up to a material point of the cable; $\mathbf{v}$ (u, v) its velocity vector; m the mass per unit unstretched length; T the tension along the cable; ϕ the angle formed between the tangent of the line at any point along it, and the horizontal; and ε the local strain. Assuming that the tension along the line can be expressed in terms of its elastic strain in the form:

$$T = f(\varepsilon) \tag{1}$$

and its spatial derivative by:

$$\frac{\partial T}{\partial s} = \frac{\partial f(\varepsilon)}{\partial \varepsilon}\frac{\partial \varepsilon}{\partial s} = f'(\varepsilon)\frac{\partial \varepsilon}{\partial s} \tag{2}$$

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