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Analysis of the Dynamic Response and Static Stability of a Discus Buoy with Articulated Keel

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ABSTRACT

Discus buoy is among the most common devices for estimating wave spectrum. In this paper a discus buoy with articulated keel is considered. Effect of the relative joint position on the dynamic behavior and the static stability of the system is evaluated. First the static stability of the system is analyzed, and the limit for static stability of a discus buoy as a function of joint position is carried out. Then the dynamic behavior of the system in a planar motion (with three degrees of freedom) is considered and the effect of joint position on dynamic behavior of the system is determined. To this end the nonlinear equations of motion of the system are derived using Kane's method. The equations of motion are then linearized assuming small relative motion of buoy with respect to water. The linearized equations are employed to obtain the natural frequencies and mode shapes as well as the equivalent damping ratio of the system in pitch motion as a function of joint position. Finally, the effect of joint position on transfer function of the system is presented.

KEYWORDS: discus buoy, articulated keel, static stability, dynamic stability, Kane's method.

INTRODUCTION

Wave parameters are among the most important quantities which are normally measured by buoys. To evaluate the directional wave spectrum, at least three quantities have to be measured. As discus buoys can properly follow the wave profile, their heave, pitch, and roll are used as the triplet, based on which the directional wave spectrum are estimated. Clearly the closer a buoy follows the wave surface, the more precise would be the estimated directional wave spectrum.

In contrast with other floating systems, which are normally designed for maximum possible static stability, the buoy systems have to have a good balance between the dynamic response and static stability. That is because, an increase in static stability, decreases the tendency of the system for tracking the wave surface, and consequently decreases the precision of the measurements. A solution to this problem would be the use of an articulated keel (Fig. 1). It can decrease the static stability in small oscillations, compared to a rigidly attached keels, while ensuring enough static stability in large oscillations.

Many researchers have studied the dynamics of moored buoys, either considering the buoy dynamics alone, or buoy and its cable simultaneously. In a recent research Leonard et. al (1993) have studied the nonlinear motion of tethered floating buoys. Barstow and Hang (1994) have shown that a good design of cable-hull system can reduce the effect of mooring system on the measured data, significantly. Stability of a discus shaped buoy has been studied by Nagai and Kakuno (1974), and Nath et al. (1980). They conclude a discus buoy with no stabilizing keel and small diameter has low reliability in capsizing. To increase the system reliability they suggest either use of an stabilizing keel or increasing the buoy diameter. Chunqun (1989) has determined the effect of an articulated keel on the static stability of a discus buoy. The dynamic response of different buoys is studied by Hoffman et al.(1973) for different kind of buoys, mathematically as well as experimentally.

In this paper, effects of the joint position of an articulated keel on the static stability and dynamic response of a buoy are studied. In the next section, after this introduction, derivation of equations of motion is presented. In the third section the effect of joint position on, dynamic stability, magnification factor and frequency response, of the system are determined. The static stability of the system is considered in the fourth section, and the last section concludes this work.

EQUATIONS OF MOTION

Before developing the equations of motion it should be noted that in the following text, vectors, dyadics, columns, and matrices are shown by bold face letters;'$\rightarrow$' at the top is used to represent vectors and dyadics as opposed to matrices. Right subscripts indicate numeric

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