

## **Responses of Multi Point Mooring Systems Under the Influence of Different Sea Conditions**

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### **ABSTRACT**

In this paper, two multi point mooring systems which are under the action of periodic wave excitation are considered in order to find out the approximate responses by using Runge Kutta Method. One of the mooring systems is anchored to the seabed with four mooring lines while the other is anchored with six mooring lines. On both systems, a strong nonlinearity is described by increasing restoring force. For possible mooring line densities, change in excursion downstream and tension at the buoys are taken into account respectively. By introducing different sea conditions into these multi point mooring systems, wave force acting on each system is observed. For certain excitation frequencies a number of chaotic phase diagrams are obtained which yields into instability of these systems. At the end, comparison of the two systems is figured out to understand the effect of number of mooring lines on the responses of each system.

**KEY WORDS:** Multi point mooring systems; Static catenary line mooring; Wave drift force; Runge Kutta Method.

### **INTRODUCTION**

Nonlinear dynamics of ocean structures has been studied out widely. Abkowitz (1972) presented a hydrodynamic model in order to analyze the motion of a vessel. Bernitsas and Chung (1990) studied the horizontal plane motions of a ship moored to two terminals and also used chains as mooring lines. Moreover, effect of mooring line arrangement on the dynamics of spread mooring systems was carried out by Bernitsas and Garza-Rios (1996). On the other hand, Bernitsas and Kim (1998) analyzed the effect of slow drift loads. Effect of second order slowly varying wave drift loads is studied by Bernitsas, Matsuura and Andersen (2004). Kim and Bernitsas (1999) gave a general idea about spread mooring systems by studying the nonlinear dynamics and stability of these systems. The effect of size and position of supporting buoys on the dynamics of spread mooring systems was carried out by Garza-Rios and Bernitsas (2001). Stability analysis and bifurcation theory are used to determine the changes in spread mooring system dynamics in deep water. Using harmonic balance method Umar, Ahmad and Data (2004) studied the stability analysis of a mooring

system. In this multi point mooring system, an additional geometric non linearity is generated with the association of mooring line angles. Whether the traditional way of mooring in shallow water is to use steel chain or wire rope in the form of a catenary, as water depth increases, the angle of the catenary at a buoy becomes steeper. The steep catenary initially produces very little horizontal restoring force, and excessive platform motions can result. For a better understanding about the nonlinearity under different excitation frequencies, different sea conditions are introduced into these mooring systems which have the exact same geometric properties have been compared. Effect of number of mooring lines on the responses of each mooring systems is analyzed.

### **MATHEMATICAL MODEL OF THE SYSTEMS**

In a multi point mooring system considering a single degree of freedom, the equation of motion for surge under the influence of harmonic excitation can be given by

$$m\ddot{X} + C\dot{X} + R(X) = FSin\theta \quad (1)$$

Where

$$R(X) = k[X + b\text{sgn}(X)] \times \left\{ 1 - \sqrt{\frac{d^2 + b^2}{d^2 + [X + b\text{sgn}(X)]^2}} \right\} \quad (2)$$

According to the Eq. 1,  $m$  is the sum of  $m_s$  and  $m_a$  which are system and added masses respectively,  $C$  is the damping coefficient including structural and hydrodynamic damping where hydrodynamic mass is considered to be the 5-8 % of the ship's mass which leads the damping to be small (Journée and Massie, 2001). On the other hand, structural damping is idealized as proportional to the mass and stiffness (Umar, Ahmad, and Data, 2004). It is possible to ignore nonlinear effects due to hydrodynamic damping.  $b$  and  $d$  are the distances between mooring lines which are illustrated in Figs. 1-2.